

## **Overcoming piano-roll limitations: Pachmann plays Sabouroff's Polka**

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**ABSTRACT:** This article documents a minor but charming moment in the history of Russian music. It involves the little-known Russian composer Peter Petrovich Sabouroff and the well-known Ukrainian/Russian pianist Vladimir de Pachmann. In 1906 Pachmann recorded a piano roll in which he added improvisations to a Polka composed by Sabouroff. I use the roll to create a previously unavailable score of the composition (including the improvisations) and an audio rendition of Pachmann's playing of it. This rendition does not use a physical reproducing piano; instead, the details recorded on the roll were mechanically digitised and then converted to sound by computer means. Piano roll recording technology had at least three substantial limitations. One limitation is newly discovered here: uncertainty as to which notes were actually played by the pianist; it is dealt with by editing the data. A second limitation is well-known: loudness was recorded at only two levels for the whole keyboard at any one time (though it could vary over time); it is dealt with by a novel algorithmic method. A third limitation concerns pedalling: only two levels were available, fully on or fully off; it is dealt with by editing based on listening. Finally, a new method of randomising the loudness attempts to give the rendition a more human quality than either the roll itself or the deterministic loudness algorithm could, by themselves, provide.

**KEY WORDS:** Historical piano recordings; piano rolls; Vladimir de Pachmann; Peter Petrovich Sabouroff; loudness nuancing; randomisation techniques

### A rare piano roll

The famous pianist Vladimir de Pachmann (1848-1933)<sup>1</sup> made not only many gramophone recordings but also many piano rolls.<sup>2</sup> His first piano roll session, in Leipzig on 19 February 1906, produced 25 rolls for the Welte-Mignon reproducing piano. Of those, the last in the catalogue was number 1228, entitled “Sabouroff – Polka Improvisation.”<sup>3</sup> Whereas most of those rolls were released fairly promptly, this was the last to be released, in December 1929, thus nearly 24 years after the recording had been made and in the year after Pachmann had retired. A possible reason for the delayed release is that, as will be seen shortly, the composition was hardly one to be taken very seriously, and one can readily surmise that it was recorded just as a favour to one of Pachmann’s friends, possibly without any intention to release it publicly. In any case, no surviving copy had been known for many years until I was fortunate to obtain one in 2013, thus possibly the only known copy today. The rather small amount of editing and care apparently taken with this release turn out to have a possible advantage here in that it has allowed more than usual of the original recording process to be observed in the resulting roll.

The Russian Sabouroff (Saburov) family was prominent over some generations.<sup>4</sup> The patriarch was Peter Alexandrovich Sabouroff (1835-1918), a diplomat with distinctions in several fields including chess and antique collecting; he had studied piano with Adolphe von Henselt (1814-1889).<sup>5</sup> A son, Peter Petrovich Sabouroff (1880-1932), had studied composition at the St Petersburg Conservatory from 1909. His “Love Symphony” was given its première in Monte Carlo on 6 May 1925.<sup>6</sup> Eleven of his scores, unrelated to the present work,<sup>7</sup> are held at the Bibliothèque nationale de France, but no further details of his career as a composer are known to me. It seems, therefore, that Peter Petrovich is most likely to have been the composer of the present piece, and that Pachmann had known his father Peter Alexandrovich and made the recording as a favour to his friend the father – it may be noted that not only

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<sup>1</sup> For more information on Pachmann see the web site <http://nettheim.com/pachmann/>, retrieved 24 February 2019.

<sup>2</sup> Piano rolls are continuous rolls of paper containing punched holes corresponding to the notes played, as well as to some other features of a performance; they were in widespread use in the early 20th century. For more information on piano rolls, especially those made for a reproducing piano, see [https://en.wikipedia.org/wiki/Piano\\_roll](https://en.wikipedia.org/wiki/Piano_roll), retrieved 24 February 2019.

<sup>3</sup> For more information on Pachmann’s rolls see the Pachmann discography/rollography <http://nettheim.com/pachmann/discography/>, retrieved 24 February 2019.

<sup>4</sup> I had begun this research knowing the roll’s title, given above, but not the meaning of that title. The word ‘Sabouroff’ seemed to indicate a type of Polka, as some authorities had thought, but no information was available about it. For instance, Smith and Howe (1994) listed it as a genre, not as a composer (pp. 190, 438, 822, 694). Pursuing the Henselt connection eventually led me to an obscure student of composition, and so the fuller significance of the roll’s title is now revealed.

<sup>5</sup> “The piano, which he had studied under Adolf Henselt, and chess, were amongst his favourite diversions” (Simpson, 1929, p. 19).

<sup>6</sup> *British Chess Magazine*, July 1925, p. 305; also retrieved 24 February 2019 from [https://en.wikipedia.org/wiki/Peter\\_Petrovich\\_Saburov](https://en.wikipedia.org/wiki/Peter_Petrovich_Saburov).

<sup>7</sup> All are vocal music (most in a contrapuntal style) except one, a “Plainte” for piano published in 1931 marked *Andantino molto moderato* and bearing no resemblance to the present Polka or to dance music in general.

the father but also Pachmann had had quite close ties with Henselt.<sup>8</sup> At the time of Pachmann's recording, Peter Petrovich was 26 years old and had not yet begun his studies of composition at the Conservatory, which is consistent with the modest level of compositional skill evident here. It is also conceivable, although it seems less likely, that the father was the composer of the piece. In any case, despite the slight significance of the composition, the improvisations added by Pachmann provide very welcome examples of his characteristic musical gestures. I have found no background information on this roll itself in the available documentation on Pachmann, on piano rolls, or on the Sabouroff family. The four persons involved are shown in Figure 1.<sup>9</sup>



**Figure 1.** From left to right: Adolf von Henselt (1814-1889), Peter Alexandrovitch Sabouroff (1835-1918), Vladimir de Pachmann (1848-1933) and Peter Petrovich Sabouroff (1880-1932).

The Polka genre was already well established by the time of Pachmann's roll recording. This genre occurs in a number of sub-types, one of which had some connection with the Russian Military forces. Polkas are generally taken briskly, with just an occasional reprieve for the dancers.

### Musical score

In the absence of a previously existing score of Sabouroff's Polka, I have derived one from the roll (Figure 2). Details of its derivation will appear throughout the paper. This score is intended to serve two purposes: (i) to provide reference points – these will assist in studying the roll and in demonstrating the details of the present audio implementation – and (ii) to enable interested readers to play the piece.<sup>10</sup> In doing this, I acknowledge that some details are necessarily uncertain.<sup>11</sup> Further, the two purposes mentioned are somewhat conflicting,

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<sup>8</sup> See for instance the prefatory note to Pachmann (c.1888): "Any alteration in the Notes is made with the approval of the Composer, and by his wish published. – W. De P."

<sup>9</sup> Sources: (a) Painting by August Grahl [https://commons.wikimedia.org/wiki/File:Adolf\\_Henselt\\_\(1814-1889\)\\_painter\\_August\\_Grahl.jpg](https://commons.wikimedia.org/wiki/File:Adolf_Henselt_(1814-1889)_painter_August_Grahl.jpg) retrieved 24 February 2019; (b) Source not given, <http://www.chesshistory.com/winter/extra/saburovs.html>, retrieved 24 February 2019; (c) *The Worcester Spy*, Worcester, Massachusetts, 29 September 1899, page 1; (d) *American Chess Bulletin*, November 1911, p. 246.

<sup>10</sup> This score fulfils the task proposed by Colmenares (2011), p.73: "Finally, we note that once piano rolls are converted to MIDI, it is easier to convert them to musical notation if desired. That would be especially useful for any rolls that contain improvised music or (if such rolls exist) music for which scores are no longer available."

<sup>11</sup> The quantisation of notes to locations within the bar, including the assignment of near-simultaneities to

requiring compromises, for the notation of music composition is normally simpler than would closely follow performed nuances. Thus dynamic markings in the score may differ from those in the representation of the performance (Figures 7b, 8). Another example of compromise arises in bar 1, where the second chord in the right-hand was probably composed with the notes D and F, matching the many recurrences of the figure later in the piece; however, the present version of the score is useful here in that it more nearly matches the roll. The roll records both Sabouroff's composition and Pachmann's improvisations upon it, and both are included in the present score. The main improvisations may be assigned to bars 21-24, 68, 89-92 and 100, and smaller improvisational effects might have been added at other places.

Errors on the part of the pianist in playing wrong notes were occasionally inferred. Such errors were understandable, for the piece is by no means a masterpiece of the repertoire, so Pachmann would have practised it perhaps just a few times, rather than for public performance. Those errors have been corrected in the score and in Audio 1 when the inference seemed strong enough, while they remain deliberately uncorrected in Audio 2.

Errors on the part of the roll-recording process were also found, and these are instructive for the study of piano-roll limitations; details will be shown below. Some such errors were demonstrable with little doubt, while others were less certain. The score provided here includes corrections where they are clearly or likely appropriate, though I have preferred to err on the side of restraint in deciding whether to make such corrections. Corrections which I have made to the roll data are not identified in the score, but they will be discussed below. Figure 2, the score of the Sabouroff Polka prepared by the present author, can be seen overleaf.

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vertical chords, was carried out by ear and was not usually in doubt in this music, given the simple and clear metrical structure of the polka. The occasional free improvisations, however, allowed more options for the transcription, and other notations are conceivable. The score provided here may be compared with Audio 1 and Audio 2.

# Polka

by Peter Petrovich Sabouroff (1880-1932) \*

Edited by Nigel Nettheim © 2016

From a piano roll “Sabouroff-Polka Improvisation”, Welte 1228,  
recorded on 19 February 1906 by Vladimir de Pachmann.

The roll includes improvisations by the pianist; they are included in  
this edition.

\* or, less likely, Peter Alexandrovitch Sabouroff (1835-1918)

# Polka

P. P. Sabouroff

Edited by Nigel Nettheim (© 2016)

From a piano roll, with improvisations, by Vladimir de Pachmann (1906)

**Allegretto**

*p* *simile*

6 *una corda*

11

16 *f* *p* *f* *tre corde*

21 *8va* *rit.* *p subito* *una corda* *tre corde*

25 a tempo

mf

8va -

29

8va -

33

37 stretto

41

8va -

4

[45] *a tempo*

*p*

*ped. simile*

[51]

*8va*

*f* *p*

[57]

*8va*

*f*

[63] *8va* *loco*

*dim.* *p*

*una corda*

[68] *ritenuto* *a tempo*

*pp* *p*

*senza ped.*

71 *accel.*  
(una corda)

77

83 *più accel.* *rit.* *mf*  
Red. \* Red. \* Red. \*

89 *a tempo* *p* *pp* *tre corde*  
Red. \* Red. \* Red. \* Red. \*

96 *stretto* *mf* *sf* *8va* *8ba*  
Red. \* Red. \* Red. \*

Detailed description: This musical score is for a piano piece, spanning measures 71 to 96. It is written for a grand piano with a treble and bass staff. The key signature has one sharp (F#). The score includes various performance instructions: 'accel.' (accelerando) at measure 71, 'più accel.' (further acceleration) at measure 83, 'rit.' (ritardando) at measure 84, 'a tempo' (return to tempo) at measure 89, 'p' (piano) at measure 89, 'pp' (pianissimo) at measure 90, 'stretto' (faster) at measure 96, and '8va' (octave up) and '8ba' (octave down) at measure 96. Dynamic markings include 'mf' (mezzo-forte) at measures 84 and 96, and 'sf' (sforzando) at measure 96. The instruction '(una corda)' is written below the first system. The score is divided into five systems, each with a measure number in a box at the beginning. The bottom of the score features a series of 'Red. \*' markings, likely indicating a reduction or a specific performance technique.

## RENDERING THE ROLL PERFORMANCE

The roll was not played back on a physical reproducing piano because today few if any reproducing pianos are found to be in a suitable condition. It would also be impossible to calibrate such a piano to conform with the unknown properties of the instrument that had been used for the initial recording. Instead, a method was used that may be called “reconstitution” of the roll recording (Nettheim, 2013). That method required three procedures: digitising, editing and playback. The details of those procedures will now be explained; the result after editing by the present author is given in Audio 1 and, for comparison, a rendition without any such editing is given in Audio 2 (the comparison shows only relatively small differences because of the relatively straightforward and unnuanced materials of this composition). A list of the audio examples in this paper is provided in Appendix C.

[Audio 1](#). Rendition of the Sabouroff Polka played by Vladimir de Pachmann, prepared by the present author from a roll. Editing, including algorithmic loudness and randomisation, is present.

[Audio 2](#). Rendition as Audio 1, but with no editing by the present author.

### Digitising

The roll was digitised mechanically to extract all its data in numerical form.<sup>12</sup> The resulting data was taken as input to a custom computer program. That program serves four functions: (i) it implements any desired manual or algorithmic editing, (ii) it graphs the data, (iii) it produces a corresponding midi file and (iv) it invokes the Pianoteq program to play the midi file and create an audio file from it.

### Editing

#### *Which notes did the pianist play?*

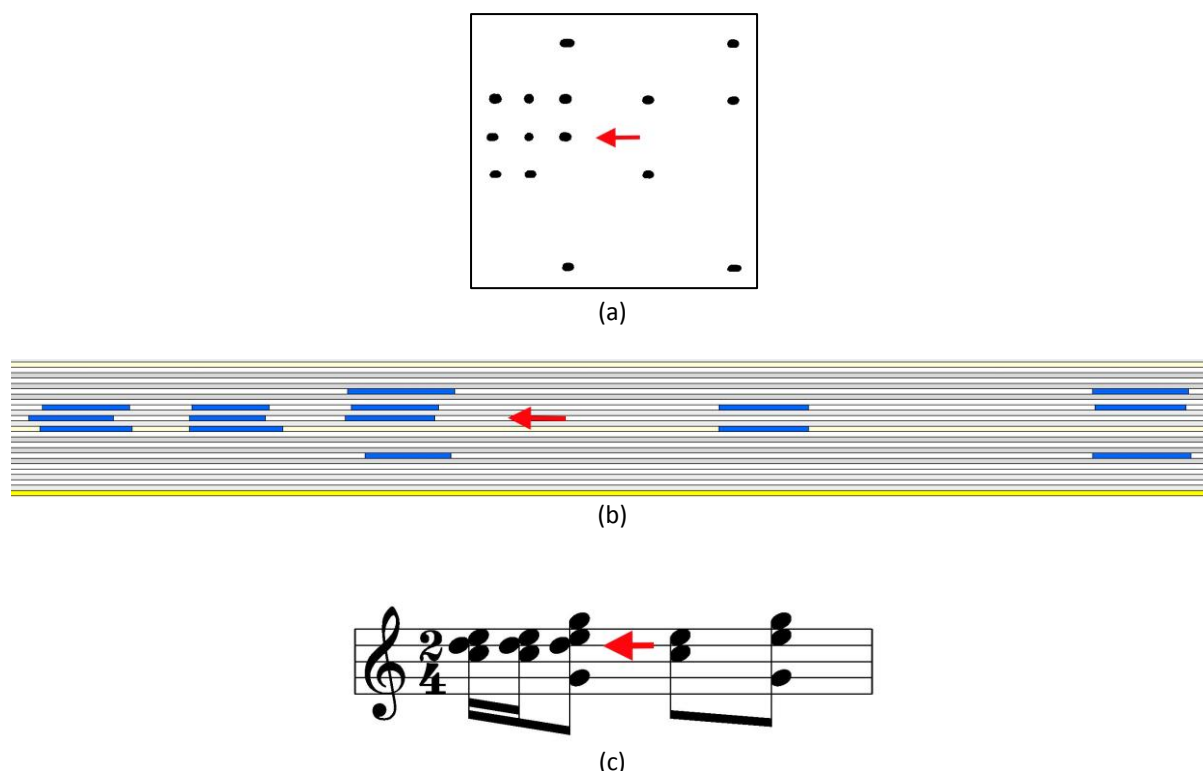
##### *Faulty roll-recording technology yields wrong notes: a first example*

It might be thought that piano rolls contain a reliable record of the notes that the pianist played (whether or not pianists made any errors themselves). However, the present roll demonstrates to the contrary, that errors could occur that were caused by the recording process itself, thus requiring editorial correction. This is seen in the first bar, where a C-major chord contains, on the roll, three extra notes, D5 in close position, that could not conceivably

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<sup>12</sup> Peter Phillips of Sydney kindly made his custom roll-reading machine available. Measuring the holes on the paper would not be sufficient, for a somewhat indirect method, including certain delays, was used when the holes were converted to sound on a reproducing piano. A process of ‘emulation’ is applied to take the encoding of the loudness and pedalling into account, including the indirect encoding; some choices are available in specifying the details of the emulation, but in practice the choices seem to make little difference. It may be noted that not only static loudness levels but also *crescendo* and *diminuendo* effects were encoded on Welte rolls (Smith and Howe, 1994, pp. 30, 53-56; Phillips, 2017, pp. 210-212). In the present case the emulation will be taken into account only in broad outline because the loudness and pedalling will be handled by an independent reconstitution procedure. Different methods of digitising piano rolls have been used by others, often via optical scanning rather than the mechanical reading used here (Colmenares et al., 2011; Shi et al., 2017).

have been sounded by the pianist (Figure 3 and Audio 3).



**Figure 3.** Bar 1, right hand part. Three views indicating, with red arrows, the spurious notes D5. (a) photocopied extract from the scanned paper roll; (b) piano-roll graph created by my custom program from the roll after conversion to midi data; (c) score derived from the piano-roll graph and audio rendition.

**Audio 3.** Bar 1, right hand part, unedited rendition from the midi file used for the graph in Figure 3: (i) tempo 100%, then (ii) tempo 30%.

One is naturally led to search for an explanation of those three spurious notes. Their mistaken appearance on the roll was clearly a result of faulty Welte roll-recording technology, but no direct evidence of that technology survives because the Welte factory was completely destroyed in November 1944, and the method had been a closely-guarded secret.<sup>13</sup>

For the present purpose it is, fortunately, not necessary to know the mechanism that caused the error, for the observation of the error and its correction are enough. Nevertheless, it might be helpful to discuss a possible roll-recording method, even though it must remain speculative. The closest approach to a reliable indication that I have come across is seen in a documented patent filed for a contemporary roll-recording company, Ampico. On that basis, a recording method has been suggested (likely to apply, perhaps with modifications, to all or most mechanisms in use, whether those of Ampico, Welte, or another company): when a key

<sup>13</sup> The secretiveness might have been maintained for purely commercial purposes, or conceivably out of embarrassment over the amount of editing sometimes required to make the notes appearing on the roll correspond sufficiently well with those appearing in the score which was usually available.

is depressed, a metal or carbon rod attached beneath the key dips into a trough of mercury to complete an electrical connection (see Appendix A).

It is easy to imagine problems arising from the adjustment of the recording mechanism just described. The trough of mercury would have to be accurately maintained, for if it were slightly overfilled unwanted contacts could occur, resulting in extra notes or, if slightly underfilled, intended contacts might not occur, resulting in missing notes. Similarly, some features of the rods would be subject to slight variability which could lead to inaccurate recording. Apart from the roll-recording mechanism, the condition of the piano-playing mechanism would also be subject to variation, including the degree of compression of the various component felts, which could affect the accuracy of the recording. The present recording was one of 25 made on the same day, again raising the question of calibration and maintenance.

Pianists might at any time let a (playing or non-playing) finger lightly touch a non-playing key, allowing that key to be depressed slightly, in the knowledge that it would not set a string in motion and would thus cause no sound to be heard. This is a commonplace of piano-playing, and of no consequence unless the playing is being recorded by measuring key displacements. Such a slight depression of a key could produce electrical contact if the recording apparatus were slightly too sensitive in that instance. In the present case of the D5 notes in bar 1 that is what seems to have happened, and other such cases will be seen later. It should be noted that even if those D5s were sounded very faintly in the playing, they would be recorded on the roll with a loudness fully equal to that of the surrounding notes because of a limitation of roll-recording technology concerning loudness levels, discussed later.<sup>14</sup>

It was mentioned above that the present roll was most likely a somewhat light-hearted and perhaps almost frivolous project, released in apparently very small numbers only many years after having been made. The editing which might normally have been carried out might, therefore, not have been carried out to the usual extent here, if at all. That could be to our present advantage in revealing some properties of a roll before the stage of editing it, and it could also explain why most rolls are more defensible in respect of editing before their release than is the present one.<sup>15</sup>

The above explanation must remain partly speculative, but it receives rather strong circumstantial support from the present case of the three extra D5 notes. As far as I am aware, this is the first time this phenomenon has been reported. Whether or not it is essentially a true explanation in all its details is unimportant for the present purpose; I have in any case deleted those notes from my score and from my sound rendition (Audio 1).

### *Faulty roll-recording technology yields wrong notes: further examples*

After the case of the three D5 notes in bar 1 had been encountered, other cases in this work

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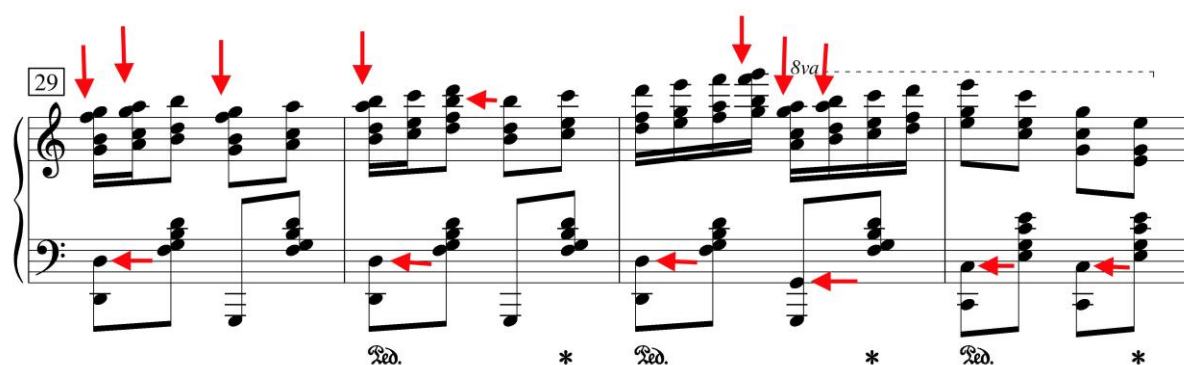
<sup>14</sup> To require recording pianists to avoid any such slight depression of the keys would be to require an overly-careful kind of piano playing. Piano technique varies considerably between pianists but few held all non-playing fingers high, and certainly not Pachmann, judging from surviving descriptions of his playing and a 1923 silent film.

<sup>15</sup> The other 24 rolls Pachmann recorded on the same day apparently do not show very unusual features of the kind described here for the present roll; those other rolls, and the ones recorded for Welte by other performers around the same time, await close study in these respects in a future project.

became candidates as examples of the same limitation of the recording process. In some cases, no certain judgment could be made but I nevertheless had to make a decision, taking into account the contexts. To set out all these cases here would be impractical, and I will show just a few.

General considerations were: (i) from the point of view of the recording mechanism hypothesised above, falsely recorded notes were more likely to appear in the present recording than falsely omitted ones; (ii) from the point of view of the composer, a fair degree of consistency and neatness of figuration was most likely present in the score; (iii) from the point of view of the performer, the playing would have been by no means as highly polished as in a piece of the standard repertoire, so that unintentionally changed notes, whether omitted or inserted, were quite possible; and (iv) from the point of view of the improviser, it was generally difficult or impossible to know exactly what was composed by Sabouroff and what had been intentionally varied by Pachmann, so guesswork was required.<sup>16</sup>

Our next example consists of bars 29-32 (Fig. 4).



**Figure 4.** Bars 29-32: musical score of the notes on the roll; red arrows indicate notes which I edited out.

Here we see in the right-hand part a number of further cases of the kind seen in Figure 3. A pattern of parallel octaves with thirds (1-3-8) is evidently intended, whereas most of the additional recorded notes do not belong there on any reasonable understanding of the music; all of the indicated notes in that example have therefore been edited out as spurious. The left-hand part shows a mixture of single notes and octaves, and many further such cases appear elsewhere in this roll, sometimes in apparently haphazard sequence. A feature of piano technique is relevant here: when the hand springs from single notes to upper triads, other fingers may well touch the non-playing keys lightly – this is a commonplace of piano technique known as “guiding fingers”, where “fingers” includes here also the thumb. This part

<sup>16</sup> Background information can be obtained from some of Pachmann’s typical improvisations which can be heard in cases where an original score is available: *Improvisation “En forme de Gondole”*, Welte roll 1227 (19 Feb 1906, thus recorded in the same session as the present roll) and again Welte roll 7208 (1925 or 1926) (on Henselt, *La Gondola (Etude) (Thema)* op.13/2); and Badarzewska/Pachmann *Das Gebet einer Jungfrau* (A Maiden’s Prayer) Welte roll 1226 (again 19 February 1906), to which may be added other occasional short improvisatory passages by Pachmann in other works.

of technique would usually pass unnoticed, but it seems very relevant in the present context. Thus the limitations of the recording mechanism mentioned above might be seen here too. To produce a version of the piece that takes this recording limitation into account and that contains coherent sequences, I decided to use either single notes regularly or octaves regularly (a decision which would not have been made in normal circumstances but which seemed needed here). Further, the comparison between single notes and octaves with respect to style and texture favours the use of single notes in my opinion, avoiding too heavy-handed an effect. I have therefore deleted those upper notes of octaves very often, and in all the cases shown in Figure 4.<sup>17</sup>

Before leaving Figure 4, it is appropriate to acknowledge an alternative explanation proposed by a reviewer: the notes which I have regarded as unintended could have been deliberately composed or improvised in order to create a certain effect. For instance, some of Rachmaninoff's improvisations and transcriptions, including his cadenza to Liszt's 2nd Rhapsody (1919) and his transcription of Kreisler's Liebesleid (1921), show somewhat similar features and are dated only a little later than 1906, the date of the present roll. In this connection one may also examine Pachmann's own other extant improvisations or arrangements (see footnote 16) where, however, only conventional figurations are found. While the available evidence is insufficient to give a definite verdict in the present case, all the notes of the roll before my editing are preserved in Audio 2, so nothing is lost and readers may certainly form their own view, as also with the question of single notes or octaves in the bass and as with other editorial questions arising in the course of this work.

A further effect with the same likely cause appears in bar 21 (see Figure 2) where the notes E4 sounded only three times on the roll instead of four times, presumably because the key was still slightly depressed after the second sound stopped, wrongly joining the second and third notes to produce a single double-length note. Those two notes have been separated in the sound file and score.

Another effect of this type seems to be present in bars 88 and 89, with the probably false repetition of two chords. This is seen as grace note-heads in the score excerpt (Figure 5).



Figure 5. Bars 87-90; red arrows indicate probably spurious notes.

### *Other editing of notes*

All the examples shown so far have been similar to the first one shown, in Figure 3, in their

<sup>17</sup> In some cases I did not delete them, for instance in the second theme (bars 45-68), providing a slight change of texture for that theme. The latter decision is perhaps more subject to debate than that for Figure 3 and the right-hand part of Figure 4, but in the absence of full evidence a decision was needed and in my opinion it is the most satisfactory one.

likely causal mechanism. A different kind of example of editing of the notes played is seen in Bar 1 (Figure 6) where a third note E3 of an initial arpeggio seems very likely somehow to have been omitted from the recording. An empty time-slot remained for it, and it was conceivably accidentally not sounded by the pianist; it sounded in the corresponding bars 25 and 69. That note seems needed to establish the metre clearly and to provide a coherent opening gesture.



**Figure 6.** Bar 1. The third note in the lower staff has been inserted editorially.

All the kinds of editing of notes applied here have now been illustrated.<sup>18</sup>

### Timing

The start and end times of notes were assumed to be reliably recorded on the roll (apart from errors of the type shown in the section *Which notes did the pianist play?*). Strong evidence on that point could have been provided if an audio recording and a roll recording of the same performance had been made simultaneously; however, no such pair of recordings is known to have been made for any music.<sup>19</sup> Strong evidence of a different kind was provided in Nettheim (2013), where a gramophone recording was compared with two roll recordings of the same piece by the same artist (all three recordings were made on different occasions). Close similarity of the timing patterns (but not of the loudness patterns) was observed across all three recordings. In the case of rapid notes such as trills and some ornaments, the timing resolution on rolls would require special investigation (including comparison with timing patterns typically found in gramophone recordings); such notes did not occur in the present piece other than perhaps in bar 31, where no strong evidence of inadequate timing resolution appears, so this matter is not pursued here.

### Pedals

Two pedals are relevant for piano-roll recording: the soft or *una corda* (left) and the sustain or *tre corde* (right) pedals. Only two levels of pedalling, 100% and 0% (fully on and fully off), were available on rolls, that is, there was no possibility of recording partial pedal. The

<sup>18</sup> Considering the large number of errors found here, it might be questioned whether Pachmann would have allowed such a recording to be released. However, Pachmann sometimes took a casual approach to recording (as well as to concert-giving), and some of his releases include blatant errors, for instance his electrical recording of the Chopin Etude op. 25 no. 3 in 1925 and especially of the Chopin Etude op. 10 no. 5 in 1927 in which he lost his way, said a few words, and started again, all of that then being released.

<sup>19</sup> This could conceivably have been out of fear of embarrassment at the non-matching of the roll to the audio.

mechanism used to record the pedals on rolls is not known, but similar problems might conceivably have arisen in the recording process for pedals as were discussed above for notes. For instance, a foot resting only lightly on a pedal and not producing any effect on the dampers of a real piano might engage the roll recording mechanism, producing a full pedal effect. This could explain the many spurious soft-pedal applications found on rolls generally.<sup>20</sup> In cases where a roll shows the soft pedal depressed and released during the course of a single note or chord, that pedal could have no effect at all on the music (such cases arose in some rolls though not the present one). Naturally the reliability of the sustain pedal on roll recordings is analogously questionable.

The soft pedal was recorded five times on the present roll. The shortest instances (1.385, 2.000 s) were deleted as spurious, while the other three were retained with slight adjustments (durations after editing 8.159, 7.906, 32.819 s).<sup>21</sup>

The sustain pedal was recorded many times on this roll. I made some editorial changes to its timing, in view of the apparently haphazard application indicated on the roll in some cases. Full pedal (100%) is sometimes too much for a satisfactory artistic effect because of ‘overpedalling’, and I assigned intermediate values to all the pedal-on depths (‘partial pedal’). In one case (bars 60-61) I changed the depth during the course of the pedalling, which a human player could achieve but which of course could never be recorded on a roll. All such pedal editing was carried out on the basis of my own judgment (taking into account especially harmony), as no systematic procedure for artistic pedalling is available; see Nettheim (2016).

### *Loudness*

#### *Deterministic loudness (no randomisation) – Motivation*

Loudness nuancing is unfortunately a major limitation of every piano-roll recording. Only two loudness levels can operate at any one time: one level for the higher notes and one level for the lower notes, a circumstance that has previously only rather infrequently been brought to attention as a factor limiting the artistic results achievable. For Welte rolls (and some other rolls) the lower notes for loudness are those up to and including F#4, illustrated in Figure 7a to be compared with Figure 7b. The method that had been used to determine the recorded loudness level on any one side of the dividing point is not known to me.<sup>22</sup> The minimum loudness achievable is limited by the roll playback mechanism, for a puff of air in the pneumatic system cannot be controlled finely enough for *pianissimo* effects without taking the risk that a note will not sound. The loudness resolution in the time dimension is also limited, that is, the speed with which the recorded loudness can change. As a result of those limitations, I found that when editing the present piece I could not make satisfactory use of the recorded levels as represented on the paper roll, beyond the relative levels for broad sections.<sup>23</sup> I therefore set about assigning loudness levels with only a little reference to those

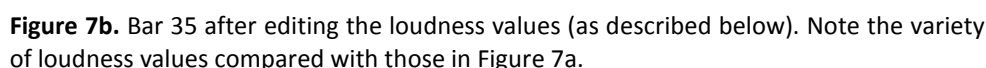
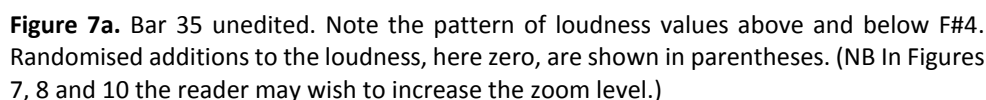
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<sup>20</sup> Such spurious applications were found, for instance, in Nettheim (2013).

<sup>21</sup> It is known that Pachmann seldom used the soft pedal, although it is seen occasionally in his published editions (including *due Pedale* in some of his Henselt editions – Pachmann, c. 1888).

<sup>22</sup> It might have been taken as the loudest of the notes on the given side of the keyboard, but this is not known with certainty.

<sup>23</sup> The values I used for that purpose resulted from the emulation applied by Peter Phillips in his roll-reading procedure mentioned earlier.

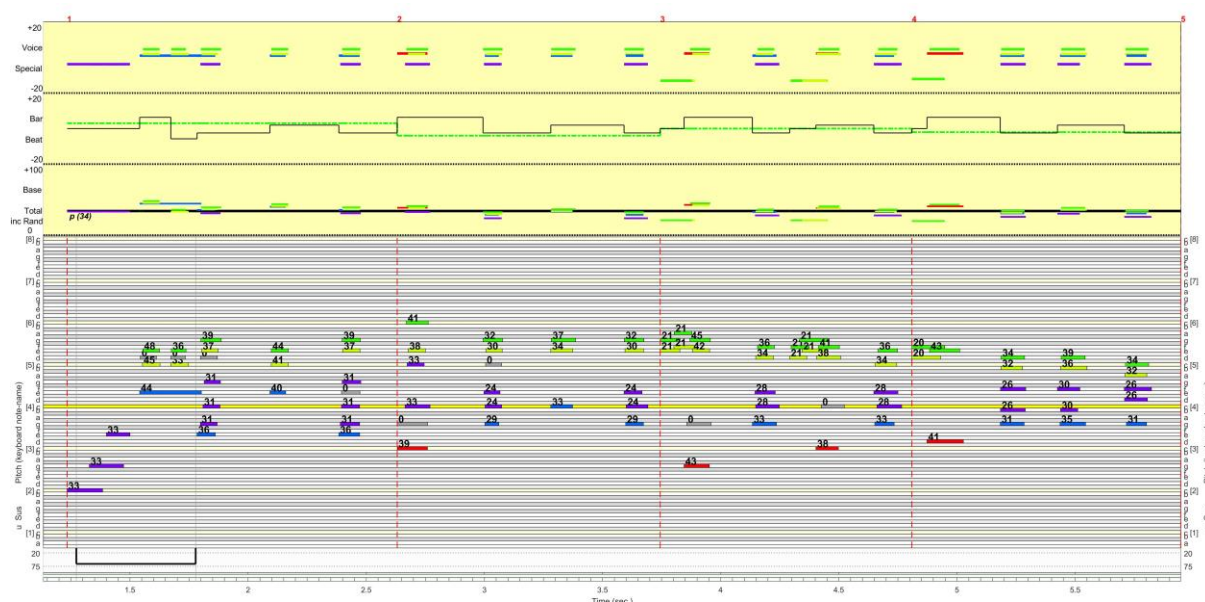


As there are nearly two thousand notes in the piece, it would have been impossible in practice to keep a manual note-wise assignment of loudness levels reasonably consistent over similar passages and over the course of the piece. I therefore used algorithmic methods with parameters set according to taste after experimentation, while bearing in mind what could be gleaned from the broad pattern of the loudness levels recorded on the roll. I used five categories of loudness level:

- (i) a *base* level, intended to apply over fairly long sections of music, generally covering a number of phrases;
- (ii) a *bar* level within each phrase, intended to provide loudness shaping over the course of a phrase typically of four bars;
- (iii) a *beat* level, intended to provide loudness shaping according to the location of each note at a given beat or division within the bar – this shaping applies to the units of a conducting-type gesture, typically covering one notated bar or else two notated bars or half a notated bar;
- (iv) a *voice* level, intended to allow distinct loudness levels to be applied to the various

voices that are usually arranged vertically through the music;

(v) a *special* level, for individual nuances not readily obtainable with the other four levels.<sup>24</sup>



**Figure 8.** Graph of bars 1-4 showing algorithmic loudness components. See the description in the text.

**Audio 4.** Bars 1-4: (i) from the unedited roll, then (ii) edited with loudness but no randomisation.

The results of the loudness specifications are seen in Figure 8 and heard in Audio 4 for the first phrase of the piece. The lower graph shows a piano-roll representation of the music, where several voices are identified by colour: the top voice in green, a voice parallel to the top voice in pale green, middle voices in purple, lower notes of chords but not the bass proper in blue, and the bass in red. Notes which I silenced as spurious are shown in grey. Bar lines and their numbers are shown vertically in red. The loudness (0-100) of each note is shown above the start of the note. The sustain pedal is shown under the notes and the *una corda* pedal, when present, in the slim green section below.

The upper graphs have a yellow background and represent the values assigned to each note in the five loudness categories just listed, as well as the resulting total loudness. The six loudness graphs are shown in pairs on three separate vertical axes. The lowest pair shows the base loudness as a solid black line, and the total loudness for each note in the colour of its

<sup>24</sup> Earlier work on modelling loudness includes Widmer and Tobudic (2003), Friberg, Bresin and Sundberg (2006) and Kirk and Miranda (2013). Their purposes were in each case different from the present one: the first took an ‘artificial intelligence’ approach for basic research, the second sought general-purpose rules, and the third proceeded from a given score including any performance indications by the composer. None took into account the influence of pedalling (see Nettheim, 2016); and results of high quality, though hoped for in the future, have not yet generally been claimed – indeed, such an individual pianist as Pachmann might not be modelled well by taking a routine or generalising approach. My present method therefore seemed preferable for my purpose.

voice (the total loudness will include randomisation, which will be discussed later and which is zero at this stage); the range for this pair of graphs is 0-100. The middle pair shows the values assigned to each bar as a green dot-dash line and the beat values within each bar as a fine black line; the range is -20 to +20. The top pair shows the loudness nuances applied to each voice coloured as before, again with range -20 to +20; if special nuances had been present they would have been shown here too.

To spell out an example of the method used, we may examine the loudness of the first melody note of the piece, E5 coloured green. Its values are: base 34, voice +5, special 0, bar +3 and beat +6. These values are summed giving 48, the total loudness of this note.

### *Deterministic loudness (no randomisation) – Discussion*

Many experiments were carried out in the course of this work, in an attempt to formulate the algorithm and to set its parameters appropriately (the settings are ultimately matters of taste).<sup>25</sup> The values in the five categories were combined by summation, which is appropriate because the loudness range 0-100 had been divided so as to provide equal increments in the perceived loudness, as far as could be managed.<sup>26</sup> Any desired total loudness for a given note could be obtained numerically by varying any combination of the five categories (that is, the categories are not mathematically ‘identifiable’), but I tried to use each category only in its intended way according to its naming, thus maintaining its significance within the scheme and therefore allowing an intuitively understandable approach to be taken. It should also be noted that any new assignment of loudness values may require pedalling assignments to be modified, whether in timing or depth or both.

Certain additional kinds of notes, beyond those mentioned above, may require their own algorithmic treatment. Two cases are illustrated in Figure 8: double-notes (those typically a third, sixth or octave below the main melody) and grace-notes. These kinds of notes are quite likely to be played relatively more softly. I therefore provided an entry in the input file to indicate a double-note, a grace-note, and a note that is both a double-note and a grace-note. A multiplicative parameter ‘melDoubMult’ was applied to the lower of double-notes. Parameters ‘graceMultLoudest’ and ‘graceMultSoftest’ were used to assign a multiplier linearly interpolated between those parameters according to the loudness it would otherwise have had.<sup>27</sup>

Values in the special category are entered manually for application to values not quite satisfactorily determined by the automated categories. They are also used to silence notes considered spurious. Ideally, that is, if the algorithms functioned very well, manual additions would not often be needed; in the present piece they were in fact used in just a few cases.

The numerical values of the deterministic loudness parameters used in the audio examples in this paper are shown in Appendix B.

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<sup>25</sup> Yet far more experiments would be needed if one aimed for general application beyond the present piece.

<sup>26</sup> This cannot be managed completely because the loudness resulting from a given value depends on pitch and other factors.

<sup>27</sup> In general, details of the algorithms are necessarily fairly complicated; spelling them out fully would be appropriate in a dissertation rather than in the present article.

### *Randomised loudness for humanisation – Motivation*

Randomisation of the loudness levels was introduced to a rather small extent in an attempt to increase the “human quality” of the sound resulting from the deterministic loudness algorithm.<sup>28</sup> The method described below, providing control depending upon specified musical factors, is the first such attempt known to me, and no claim is made for it beyond that.<sup>29</sup> Further, this method might require considerable modification for application to other pieces, and listening tests would be desirable to confirm or deny the usefulness of the results. Sources of empirical information about randomness in loudness would include recordings on various media other than rolls, most readily on a Disklavier, but output from those media has not yet been processed for this purpose to my knowledge; a considerable amount of speculation has therefore been needed here.

### *Randomised loudness for humanisation – Method*

A random loudness component was added to the previously-calculated deterministic loudness component. First, random numbers were generated from a specified statistical distribution. Each random number thus generated was then multiplied according to five algorithmic factors, producing the resultant random component. Thus the method of application was, as for deterministic loudness, mainly algorithmic. The rationale for the use of factor multiplication rather than factor addition was that the random numbers chosen from the statistical distribution should largely retain their behaviour – they should be modified by the specified factors but not combined with newly-generated random numbers, which would reduce control over the random process.<sup>30</sup> Further details of this procedure will now be given, and a numerical example provided at the end of this section.

The statistical distribution of random errors<sup>31</sup> in the loudness control of human piano playing is not known, and could be discovered by physical experimentation only in limited situations. In specifying a distribution for this purpose without the aid of empirical evidence, I made four assumptions: (i) a mean error of zero (central between playing too loudly and too softly), (ii) a certain mean absolute error, whose value is to be assigned, (iii) a distribution having the character of the normal (Gaussian) distribution,<sup>32</sup> and (iv) a certain maximum absolute error (needed because the normal distribution has no maximum or minimum, and I did not want to represent here the performance of a clumsy or novice pianist).

To implement this scheme, a variable having a standard normal distribution was multiplied by M and truncated to T, with M and T chosen to give both the desired mean

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<sup>28</sup> Randomisation of timing was not needed here, because the timings on the roll were considered to be not too highly quantised (in the absence of very short notes such as in trills).

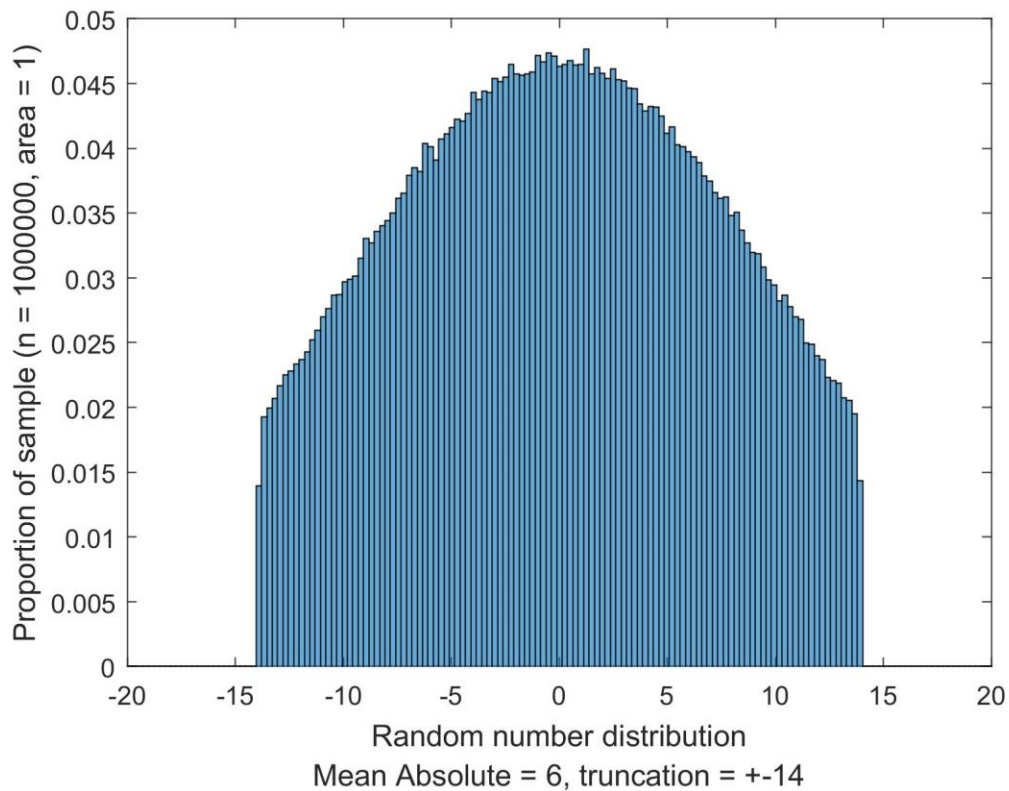
<sup>29</sup> Randomisation is not mentioned in the fairly recent reference Kirke and Miranda, 2013. Randomisation is provided in numerical form in applications such as Logic Pro ([https://support.apple.com/kb/PH27050?locale=en\\_US&viewlocale=en\\_US](https://support.apple.com/kb/PH27050?locale=en_US&viewlocale=en_US), retrieved 24 February 2019), but without the controlled relation to specified musical factors used in the present work.

<sup>30</sup> It should be borne in mind that, as mentioned earlier, the units of loudness have been matched to perceived loudness.

<sup>31</sup> The term ‘error’ is used here in the statistical sense rather than in a pejorative sense.

<sup>32</sup> It is quite possible that the distribution should instead be asymmetrical; an inverted V-shaped distribution ( $\_^\wedge\_$ ) could also be tried. However, the Gaussian distribution is a natural first attempt at representing small random errors.

absolute value 'MeanAbs' and the desired maximum absolute error 'MaxErr'. For illustration, we may desire MeanAbs = 6 and MaxErr = 14, the units being the range of loudness (0-100). The required values of M and T turn out to be approximately 10.35 and 1.35 respectively. A random sample of 1 million values from this distribution is shown in Figure 9.



**Figure 9.** Random sample of 1 million values from the distribution specified in the text.

After the mean absolute value and truncation points of the *additive* random distribution had thus been specified, the following factors were applied *multiplicatively* to each random number generated:

- (i) *Voice*: less randomness was used for outer voices where the control of loudness shaping is more important, more randomness for inner voices;
- (ii) *Pitch*: less randomness was used for pitches central to the hearing range, more randomness for more extreme pitches;
- (iii) *Chord-density*: more randomness was used for chords containing more notes (reflecting limitations of human performance and perhaps also of perception) – this is density in the pitch or vertical dimension;
- (iv) *Note-density*: more randomness was used for more rapid playing, according to the number of notes played per unit of time (the measurements were made with a moving window, weighted by the inverse of the time interval from the central time) – this is

density in the time or horizontal dimension;<sup>33</sup>

(v) *Special*: this is used to give more or less total randomness to different sections of a piece in any case that is not satisfactorily covered above.

The task of choosing suitable values for those factors is not easy and, as with all parametrisation in this kind of work, the only ultimate judge is the ear. Systematic behaviour can be sought, but in the case of randomisation so many individual characteristics of the music may be relevant that rules-of-thumb are hard to come by. Trial and error is needed, but even that is difficult because the search for good values has to be carried out in many dimensions over which the effects take place jointly. Thus a demonstration of the separate effect of each factor would be impossible and one can only try to acquire a feeling for suitable specifications by informal experimentation. Further, the effects can in some cases only be judged over fairly long sections of music, so that only a small portion of the desirable experimentation can be carried out in practice. It is however relatively easy to recognise when the mean absolute error, the truncation point, or a particular factor has been set much too high and then to reduce it in stages. Results are illustrated in Figure 10 and Audio 5.



Figure 10. Graph of bars 1-4 showing algorithmic randomness. See the description in the text.

**Audio 5.** Bars 1-4 (i) from the unedited roll, then (ii) with loudness including randomisation.

The lower graph shows a roll representation of the music as in Figure 8. The loudness (0-100) is shown above the start of each note: the final value and, in parentheses, the random component of that loudness.

The upper graphs, with blue background, represent the values assigned to each note for

<sup>33</sup> This reflects speed of note playing, not necessarily tempo as felt. Chord-density and note-density reflect note timing in different ways; both effects can be used, thus providing for chords in rapid succession.

the five randomness factors listed above, as well as the base level of randomness applying to each note (the random number generated for that note) and the total randomness (resulting from the application of the factors). Some of those seven loudness graphs are shown in pairs, using altogether five separate vertical axes. The lowest of the five graphs shows the total amount of randomness added to the deterministic loudness, colours indicating voices as in Figure 8. The next-higher graph shows the pitch factor, as a solid black line, and the chord-density factor, as a solid yellow line; here, as for the other factors, a logarithmic scale has been used because the factors are multiplicative, and the logarithmic scale itself appears at the right end of the graph (note, for instance, that the vertical distance from the value 0.5 to 1.0 is the same as that from 1.0 to 2.0 on a logarithmic scale, both representing a doubling). The next-higher graph shows the voice factor and the special factor; when no special factor applies it is not shown. The second-top graph shows the note-density factor. In the top graph the base values as samples from the given probability distribution are shown in dot-dash style, now on an arithmetical scale. Thus the top value is multiplied by those on the three next lower graphs to produce the bottom value.

We may again show the method explicitly for the first melody note, E5. The random number generated was -10.28 and its factors are: voice 0.65, chord-density 1.00, pitch 0.84, special 1.00, note-density 1.50, producing a total random component of  $-10.28 \times 0.65 \times 1.00 \times 0.84 \times 1.00 \times 1.50 = -8.42$ . This is added to the deterministic loudness 48.00 to give the resultant total loudness 40 (after rounding).

#### *Randomised loudness for humanisation – Discussion*

Assigning the parameter values for randomisation is not an easy task. A variety of musical contexts needs to be catered for, even when attention is restricted to just one piece. The contributions appropriate for the individual factors are not easy to judge, although the resulting total amount of randomness may be easier. It was often found helpful to set exaggeratedly large values first and then reduce them progressively. It may be noted that with the present very clear piano rendition, having no acoustic noise component, the effective degree of randomness may well be less than when noise is present in live conditions.

The numerical values of the loudness randomisation parameters used in the audio examples in this paper are shown in Appendix B. A few comments on the operation of each multiplicative factor in the present piece will now be made.

*Voice factor:* relatively straightforward and no specially instructive cases arose; however, the choice of the assignment of a note to the ‘bass’ or else to the ‘next-bass’ voice, which is sometimes not obvious, could influence the result noticeably.

*Pitch factor:* set to have only a moderate effect, even for the extreme pitches.<sup>34</sup>

*Chord-density factor:* set primarily to reduce randomness for fairly slow single-note passages by multiplying by less than 1, for instance in bars 23-24 and the arpeggiated bar 89.

*Note-density factor:* low in bars 23-24, 88 and 92, high in bars 31 and 86. Rapid passages

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<sup>34</sup> The highest pitches are found in bars 23, 32, 42, 61 and 62, and the lowest in bar 25.

may require more randomisation than slower passages; examples are parallel chords (bar 31) and parallel octaves (bars 41-42), or in other pieces rapid repeated notes and repeated chords, where an unnatural, almost mathematical or mechanical, quality may stand out as unwanted.

*Special factor*: ideally the factors for loudness randomisation would give good results without the use of special factors (manually entered exceptions). That stage has not quite been reached, because of the great complexity that was mentioned. Still, special factors were needed only a few times (see Appendix B) which suggests fairly good success for the randomisation scheme.

### *Errors by the recording artist*

A few note errors were evident in the roll recording. An extra note may be sounded unintentionally, an intended one may not have sounded, or a note may appear changed to another pitch. These presumably resulted either from the faulty roll-recording technology mentioned earlier or from the pianist's inaccuracy. Sometimes, as in the D5 notes shown in Figure 3, the cause was clearly the technology, but in other cases it was hard to assign the cause, as for instance the D2 recorded in bar 71 which I allowed to remain rather than changing it to C2. I occasionally corrected errors which I thought were probably made by the pianist.<sup>35</sup>

### **Playback**

For playback I chose the Pianoteq virtual piano (Modartt, 2015), a software implementation of a mathematical model of the physics of a piano's sound. Pianoteq provides a number of virtual instruments, from which I chose the D4 Classical BA one based on a Steinway model D from Hamburg ('BA' refers to the microphone placement). Each Pianoteq instrument may be modified through many parameters grouped in four categories: tuning, voicing, design and output; my modifications were mainly in voicing, where I softened the hammers and reduced the hammer noise. I set the tuning level to A440, although the 1906 recording would probably have been made at a lower level. Realism could have been enhanced by adding a little acoustic noise, but I accepted the clear sound generated. I wrote a computer program in the Matlab language to convert the values to a midi file according to the specifications required for playing the music on the chosen output device. The data for the Matlab program is a matrix, each row containing the details for one musical event, whether a note or a pedal action. I listened to Bowers & Wilkins MM-1 speakers without headphones.

### **COMMENTS ON PACHMANN'S PERFORMANCE AND IMPROVISATIONS**

No evaluation of Pachmann's performance of the original composition is possible here, both because of the evident problems with the recording technology and because the composition is modest. Since no original score has been found, it is impossible to know which smaller

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<sup>35</sup> Although there may be some desire to present an historical document containing exactly what the pianist played, the enshrinement of false sounds is sometimes considered less desirable, especially when they may be listened to repeatedly. All the sounds are, in any case, preserved in Audio 2.

improvisations Pachmann may have added to it,<sup>36</sup> but several larger improvisations are easy to spot. The most valuable one is seen in bars 23-24 (bars 21-22 may well be improvised too), which provides a welcome example of a very typical Pachmann gesture. In this connection we can avail ourselves of examples of improvisations that are clearly identifiable in other recordings of Pachmann mentioned in footnote 16. The compositional materials of his improvisations are always very simple and the attraction results from the expressive gesture in the playing of a modulation or cadence, especially from its timing and arpeggiation. The improvisation in bars 23-24 first prolongs the harmony a:V7 and then moves beautifully and smoothly to C:V7. The shaping of Pachmann's playing of such a passage would benefit from close study in the future. The modulation from G to C in bar 68 is another example of a typical Pachmann gesture. A third effective modulation is seen in bars 89-92, from a to C, again with arpeggiation and prolonging (bars 91-92 seem abrupt by comparison with bars 89-90). The conclusion of the piece in bar 100 with a sudden splash is somewhat humorous and might well also be improvisational.

### CONCLUSIONS

The composer of the work recorded on a rare piano roll has been identified fairly conclusively. Further, some severe limitations of piano rolls have been demonstrated. In that demonstration, a previously unknown limitation of piano-roll recording technology in its accuracy of recording the notes played was revealed, the investigation taking advantage of the apparent lack of editing in the production of the particular roll studied. Previously well-known limitations in the recording of dynamics and pedalling were also documented. A rendition of the roll was prepared with the aid of a custom computer program in an attempt to overcome those limitations, and may fairly be considered to have produced satisfactory results. An associated musical score was also derived, possibly the first time this has been done from a piano roll (apart from some by Conlon Nancarrow [1912-1997], which belong to a different category). The method of processing has been applied here to a modest composition, and has introduced relatively small differences compared with the original roll, but when applied to more sophisticated compositions it is likely to introduce more significant differences. The present rendition included a new method of randomisation of loudness for the sake of humanisation, involving controlling the contribution to the total amount of randomness contributed in response to each of certain specified musical factors; it is possibly also the first time this has been done and it, too, may be considered successful in this single case study, although the method is expected to be subject to modification in wider application.

It is possible that further such case studies will lead to more generally applicable procedures, providing acceptable realisations of the many thousands of rolls that, while potentially valuable, are all subject to most of the limitations that were dealt with in this paper. A balance between an approach based on routine methods and one based on the treatment of individual cases will nevertheless need to be sought; thus the application of the necessary computational methods should not be too highly automated.

In connection with the particular performance dealt with here, the opportunity to hear

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<sup>36</sup> Bar 52 might be an example of a smaller improvisation.

some examples of the shaping of Pachmann's expressive improvised phrases was a highlight; that shaping could itself benefit from close study in the future.

### ACKNOWLEDGEMENTS

I thank Peter Phillips for kindly making available his custom-built piano-roll reader, Edward Winter for advice about the Sabouroff family, and two anonymous reviewers for their helpful suggestions.

### COPYRIGHT

The score presented here and the audio rendition are copyright © Nigel Nettheim 2019.

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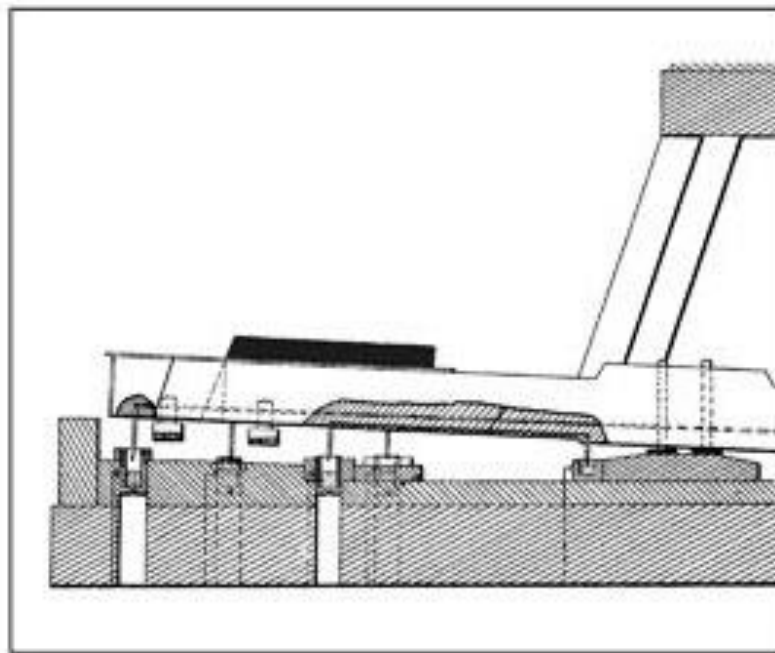
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## APPENDIX A

### A possible roll-recording method

A clue to a possible roll-recording method is provided by an illustration of a patent (Figure A1).



**Figure A1.** Diagram showing a possible recording mechanism for piano rolls. Source: Anon (n.d.) (The Pianola Institute).

The text accompanying the diagram is:

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#### The Welte-Mignon Recording Process

The Welte Company in Germany kept its recording processes a closely guarded secret, ...

...

This webpage describes the probable system that Welte used ...

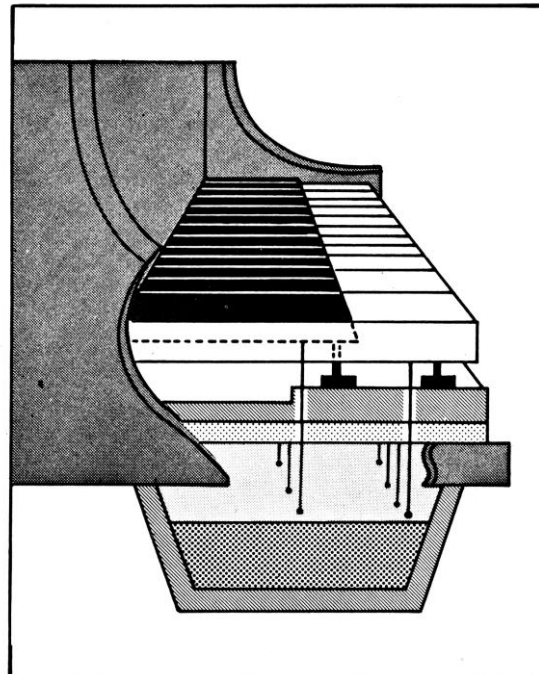
...

#### Recording the Pitches and Durations of the Notes

As the pianist played a particular note, a thin rod of metal or carbon, attached to the underside of each key, was dipped into a small cup of mercury, located in a trough under the keyboard of the piano, which spanned the whole width of roughly seven octaves. In this way, an electrical contact was made, without greatly affecting the touch of the recording piano, which had to remain sensitive enough for the most fastidious pianist. The system used must have been very similar to Charles Fuller Stoddard's 1908 design for the Ampico recording piano, illustrated in US Patent 1,095,128.

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A similar explanation of the recording method, again called “probable”, is seen in Hall (1963), p. 1. See Figure A2.



Cut-away drawing showing probable motion of carbon rod dipping into mercury trough as pressure is applied to the keys.

**Figure A2.** Diagram showing a possible recording mechanism for piano rolls. Source: Hall (1963).

The text accompanying this diagram is as follows (the bold font in which German words appear in the original has been removed here):

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Briefly, here is how the Welte-Mignon worked its magic:

The recording unit, connected by thin wires to the Stainway [Steinway] in the Welte Muskisaal, (Music Hall) contained a roll of specially aged, thin paper, marked off into 100 parallel lines. Poised over each line was a little wheel [p.34] of extremely soft rubber, with pointed edges. Each wheel [continued on p.35] was in contact with an ink supply, and in this much of the process it resembled a small offset printing press. Under the keyboard of the Steinway was a trough filled with mercury; attached to the underside of each key was a slim rod of carbon. As the key was depressed, the rod dipped into the mercury and an electrical contact was established between it and an electromagnet connected to the corresponding inked roller in the recording machine. The harder the pianist hit the key of the piano, the deeper the carbon rod would plunge into the mercury, and the stronger the current between the rod and the mercury would be. The harder the inked rubber wheel was pressed against the moving paper roll, the wider the mark it printed on the paper. The pianist's pedaling and speed of attack was captured in the same way.

After a selection had been finished, the paper roll was removed from the recording machine and run through a chemical bath to “fix” the colloidal graphite ink which had been printed on it by the rollers. This ink was electro-conductive, and when the roll was ready for playback, it was put into a master-reproducing Vorsetzer which “read” the markings in almost the same way that the magnetic printing on bank checks is used in automatic banking systems today. The Vorsetzer (it means “something set above or before” in Germany) made music as well as money.

Shortly after recording a selection, the artist returned to the Musiksaal and found the Vorsetzer “seated” at the piano where he had been playing. But nobody laughed when the Vorsetzer sat down at the piano. The results were astonishing. Extending along the front of the cabinet was a row of felt-tipped “fingers” (made the same length as a man’s, from the wrist pivot to the tips, in order to duplicate the human touch), one for each of the piano’s notes; two more felt-slippered feet stood ready above the pedals. When the machine was turned on, the Vorsetzer recreated the ink markings into the pianist’s own performance, with every pause, every shade of expression, every thundering chord. If the master roll was approved by the artist, it was then laboriously hand-punched to translate the ink markings into perforations in paper rolls which would have the same magical results when played back on a standard Vorsetzer in a music-lover’s home.

---

The above description indicates that the loudness of each note was recorded; in that case, the restriction to only two levels of loudness at any one time must have taken place only later in perforating the paper rolls. A similar procedure may have been used with respect to the depth of pedalling. It would not be surprising if the artists were impressed and gave their approval, if they heard only the playback of the master versions before the perforating. The width of the ink markings could not be transferred to the perforations on the paper rolls, so vital information was lost.

Other descriptions of a possible recording mechanism include Pätzig (1971), pp. 9-10. As mentioned above, all such descriptions are speculative, and their truth is not essential for the present paper.

**APPENDIX B****Numerical values of the parameters used for the audio examples given in this paper  
(excerpts from my custom computer program)***(1) Parameters used for deterministic loudness:*

```
loudV = [10, 8, 0, 14, 10];
```

```
loudV = loudV - mean(loudV);
```

Comment: The values in the array thus average to zero, but not necessarily the effects applied to the voices actually present.

```
exaggerationFactor = 0.6;
```

```
loudV = loudV * exaggerationFactor;
```

```
loudParameters.bass = loudV(1);
```

```
loudParameters.nextBass = loudV(2);
```

```
loudParameters.central = loudV(3);
```

```
loudParameters.mainMel = loudV(4);
```

```
loudParameters.nextSop = loudV(5);
```

```
loudParameters.melDoubMult = 0.2;
```

```
loudParameters.graceMultSoftest = 0.70;
```

Comment: For acciaccatura < 1, for appoggiatura > 1

```
loudParameters.graceMultLoudest = 0.45;
```

Comment: For acciaccatura < 1, for appoggiatura > 1

```
loudParameters.locResolution = 0.25;
```

```
loudParameters.location = [8 -3 0 -3 4 -3 0 -5];
```

Comment: Location within the bar (assumes 8 divisions of the bar), additive.

```
locationExaggerationFactor = 1.1;
```

```
loudParameters.location = locationExaggerationFactor * loudParameters.location;
```

```
loudParameters.location = loudParameters.location - mean(loudParameters.location);
```

Comment: Should the average be weighted in some way? Only some locations will be present as note-starts in the music, some more likely than others. Maybe each main division could average to about zero, or the averaging could be done by the program for each bar separately.

Comment: Assign the meaning of the voice numbers:

```
voiceID.bass = 1;
```

```
voiceID.nextBass = 2;
```

```
voiceID.central = 3;  
voiceID.nextSop = 8;  
voiceID.mainMel = 9;
```

### *(2) Parameters used for the randomisation of loudness:*

The random number distribution properties were set as MeanAbs = 6 and MaxErr =14, as indicated for Figure 9.

#### *Voice:*

```
voiceFactors = [0.75 1.00 1.3 1.3 1.3 1.3 1.3 0.80 0.65];
```

1 bass, 2 next-bass, 3-7 central, 8 next-sop, 9 melody.

Thus the main melody had the smallest factor.

#### *Pitch:*

```
pitchCurvePoints = [1 1.4; 44.5 0.8; 88 1.4];
```

Comment: Each pair consists of a note-number and a factor. A parabola was fitted through these points.

#### *Chord-density:*

```
chordFactors = [0.50 0.80 1.00 1.25 1.45 1.60 1.70 1.80 1.90 1.95 2.00 2.05 2.10 2.15 2.20  
2.25];
```

Comment: The  $n$ th factor in the array is used for a chord-density of  $n$  notes.

A chord in a performance will not usually have its notes played simultaneously, so a chord has to be defined suitably.

#### *Note-density:*

```
densityFactors = [.3 .3 .6 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.5 1.5 1.5 1.5 1.6 1.6 1.7 1.7 1.7  
1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7];
```

Comment: The  $n$ th factor in the array refers to a note-density of  $n$ , as defined above.

#### *Special:*

Bar 20: Special factor = 0.5 applied to all notes of the two central chords of the bar. Reason: The 'next-bass' notes were too loud because of high random numbers, and at the same time the lower intermediate notes were much softer because of low random numbers. This draws attention to the present method choosing random numbers for each note one-by-one, whereas the random numbers would better be coordinated so as to be more similar for groups of notes that belong together musically, whether as component notes of a chord or for other musical reasons. This weakness did not often interfere here, but dealing with it is work for the future.

Bar 31: Special factor = 1.4 for all notes of the bar. Reason: The musical material is of a kind that suggests that less control of loudness levels will be achieved by a human player, so that a mechanical or robotic effect is to be avoided.

Bars 41-42: Special factor = 1.4 for the whole of both bars. Reason: The same reason as for bar 31.

Bar 52: Special factor = 0 (no randomness) for the second chord of the bar. Reason: the random numbers for all the notes of this chord were negative and the chord as a whole was too soft – thus a similar reason to that for bar 20.

Bars 95-96: Special factor = 0.5 for all notes of both bars. Reason: The second G3 of bar 95 was suddenly loud because of its high random number together with the voice factor, compared with the remainder of the passage, thus similarly to the reason for bars 20 and 52. The two G3s in bar 96 were almost silent because of their low random numbers. The simplest solution was to reduce the absolute value of the base level (voiceFactors(1)) throughout the two bars.

## APPENDIX C

### List of Audio Examples

[Audio 1.](#) Rendition of the Sabouroff Polka played by Vladimir de Pachmann, prepared by the present author from a roll. Editing, including algorithmic loudness and randomisation, is present.

[Audio 2.](#) Rendition as Audio 1, but with no editing by the present author.

[Audio 3.](#) Bar 1, right hand part, unedited rendition from the midi file used for the graph in Figure 3: (i) tempo 100%, then (ii) tempo 30%.

[Audio 4.](#) Bars 1-4: (i) from the unedited roll, then (ii) edited with loudness but no randomisation.

[Audio 5.](#) Bars 1-4 (i) from the unedited roll, then (ii) with loudness including randomisation.