ITERATIVE SCORE FOR DIGITAL SOUND COMPOSITION

Peter Plessas
Department of Composition Studies and Music Production
University of Music and Performing Arts Vienna
plessas@mdw.ac.at

ABSTRACT

The composition of electroacoustic music for the recorded medium has become largely independent from the requirement to furnish a realization score. While digital technology invites intuitive compositional work in graphical audio software, a documentation of such creative activity often requires an a posteriori analysis and reverse-engineering approach. The iterative score presented here attempts to bridge the prescriptive and the descriptive nature of scores for sound compositions, that is musical works based on the transformation of recorded sound. Instructions for repeated realizations of such a composition are given in a case study, embracing a subtractive approach to problem solving with technology and providing a resource with good accessibility for visually impaired musicians.

1. INTRODUCTION

Textual or graphical scores for electroacoustic music on the recorded medium are frequently differentiated between prescriptive and descriptive scores. Prescriptive scores give partial or full instructions to realize a given work. They may also serve as a kind of parallel notation for the composer herself, used as a reference in production in order to decouple some of the decision making from the realization, while keeping track of the overall structure of the work. Descriptive scores for analyses and informed listening may employ visual representations [1] and inventories and supplementing texts [2]. They are surprisingly often created by individuals other than the composer or as a team effort. Automated transcription techniques for electroacoustic music on the recorded medium do frequently produce visual representations modeled after human auditory perception [3]. Such representations are useful in music analysis and as pedagogical support when followed along while listening as many visual scores feature a time axis similar to traditional symbolic scores. The informative value of time-varying spectral information may be questioned for its inability to group partials into events and to organize such events into auditory streams as described for the human auditory system [4]. Visual information from spectral analysis can successfully complement listening by showing in greater detail what may not have been perceived or identified by ear.

2. REALIZATION SCORES IN ELECTROACOUSTIC MUSIC

Prescriptive scores for the realization of electroacoustic music follow a wide variety of notation strategies. Early compositions submitted as application for an realization in the Cologne WDR electronic music studio were initially expected to adhere to a scheme for graphical notation [5] in order to be realized by the studio staff, not necessarily including the composer. The correlation of the audible result with the original written instructions may have been loose in such cases but these scores allow repeated realizations by other individuals, which is an easily overlooked feature. To what extent a realization by different individuals includes a subjective and artistic interpretation is an interesting question and open to further research. Its examination would certainly require multiple realizations of a work by various artists, and a differentiation of which variations are the result of unintentional influences of the technology, and which are the result of choice and taste.

John Cage's "Williams Mix" (1951-53) constitutes an early realization score for an octophonic tape composition using recorded sound. The indicated edits of the magnetic tape are influenced by random procedures and do not trace the composers stepwise decision making path. The score does not prescribe a single specific source material and hence does not allow the exact recreation of the composer's initial version, but invites individuals to realize new renditions of the piece with original sound material [6]. Automated implementations for *Williams Mix* have been created by others [7][8] allowing an easy exchange of the source sound material subjected to digital edits.

Several of Trevor Wishart's compositions can serve of examples using recorded sound as sole material. They have been described by the composer in written texts, concerning amongst other topics the sources, transformations and layout of the sound material [9][10][11]. A digital resource in [12], covering his work "Imago" (2002), includes references to the implementation of the sound transformations and to the assembly of the sounds into larger structures while also providing the actual audio files for study.

Audible influences of technological shortcomings in multiple renditions of a compositions can be reduced by working entirely in the digital medium. The move to such a workflow however reduces the need, or desire, for a realization by others, as unlimited cycles of design-rendering-evaluation of digital music become possible. This workflow introduces the danger of getting lost in a vast array of possibilities and of being able to revoke all decisions by infinite "undo" steps in software [13]. Cheap and accessible personal technology furthermore helps the composer to carry out all production steps herself, eventually becoming a monolithic luthier-composer-performer, a *hyphenated musician* [14].

Realization scores in form of pure software code are often targeted at works predominantly realized with sound synthesis. [1] This owes to the fact that digital synthesis may be sufficiently well described in textual or graphical form using a limited and standardized set of digital signal processing (DSP) blocks. Digital synthesis scores are self-sufficient without any additional audio data provided [15], but do often exhibit a structure that does not reflect the chronological development, for example a division between synthesis instruments and score statements. When well documented with comments and explanations, such software code may nevertheless allow a purposeful study by a human reader. Software that permits the performance of music by live coding may furthermore permit a chronological tracking and playback of all text input by means of a history file [16]. Modifications to *composed instruments* [17] can likewise be analyzed as a kind of interpretation by their players, either in advance or during a musical performance [18].

For sound compositions in the tradition of acousmatic music, which use audio recordings as their primary source material, a realization score is generally difficult to furnish. This is especially—and paradoxically—the case when a musical work is created with a digital audio workstation (DAW). Graphical multi track editing and mixing software offers an intuitive way of working with many layers of recorded sound, permitting its precise arrangement in time and transformation with effect plug-ins. While such real-time plug-ins are the de facto way of shaping audio signals in a DAW, they are limited by not being able to access the entire length of the signal in one step due to their block-wise processing. This is a drawback to composers wanting to redesign the time axis of an audio recording with signal processing algorithms. The Audio Random Access (ARA) extension [19] to existing audio software standards permits such access, although plug-ins returning audio data of different durations to the host DAW may produce unforeseen conflicts in the time line. Despite the obvious advantages of real-time operation, composition has been outlined as being essentially a non-real-time process in literature [20].

3. THE ITERATIVE SCORE

An iterative score formalizes a stepwise realization of an electroacoustic composition using recorded sound. When the actual audio source material has been made available, the composition can be studied, re-created and optionally modified by individuals other than the composer. An iterative score will hence serve as a prescriptive as well as an descriptive score. Its descriptive value can be greatly enhanced when its stepwise instructions are furnished with text comments by the composer. The creation of an iterative score for sound compositions is greatly facilitated by using software that offers the transformation of audio files with a text-based command-line interface working in non-real-time. Example software include the Composer's Desktop Project (CDP) [21], Sound Exchange (SoX) [22] and to some extent scriptable graphical audio editors and any DSP language offering stepwise execution. Restricting oneself to software that uses the operating system command line interface (CLI) offers a standardized and modular interface to multiple sound transformation programs as well as to powerful file system operations. The most important CLI feature in this context is the built-in command history and its ability to export a list of all typed commands into a text file, which can then be redacted to yield the steps of an iterative score. These steps will then allow repeatable realizations, different or identical to the original work. An iterative score represents the minimum number of steps required to arrive at the final composition starting from the source audio material. It does to some extent give a chronological account of the creative path the composer has taken but does not give evidence of all the decisions a composer has taken of which some were eventually rejected. For example, *shadow edits* [23], which did not make it into the finished piece, but which were possibly necessary to arrive at the accepted edits, are undocumented. An iterative score should therefore not be considered a close representation of the composer's way of working, but a sequence of steps that were accepted as suitable for a specific composition. Iterative scores however permit other individuals to inspect the intermediate results of the sound transformations and to alter technical parameters, observing their impact on the final sound material.

4. CASE STUDY

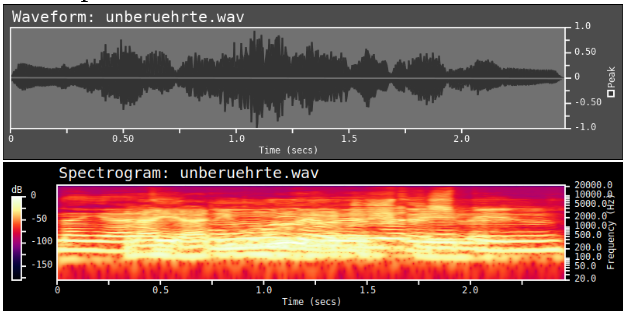
The feasibility of an iterative score that encompasses prescriptive as well as descriptive functions is demonstrated with regard to the author's sound composition "Affair: Seven plus or minus two" (12 minutes, stereo) for the recorded medium. Commissioned for the dance performance "Affair" by Christine Gaigg in 2019, its title is inspired by George A. Miller's publication regarding human capacity for processing information [24]. All five parts of this composition were realized almost exclusively using the command-line version of the CDP 7.1 software and short recordings of human speech taken from the performance text. CDP was chosen for its bewildering array of sound transformations targeted at electroacoustic music such as spectral or waveset processing, and for its GPL license and cross-platform availability. No operating system commands were used in order to keep the realization independent of the actual platform used. For the fifth part of the composition, "5. Code Adam", the iterative score is presented next.

4.1 Source material

The source material is the mono file `unberuehrte.wav` (2.46 seconds), in which several male and female voices speak the german words "... die Unberührte spielen." ("... playing the pristine.") together. This recording has been se-

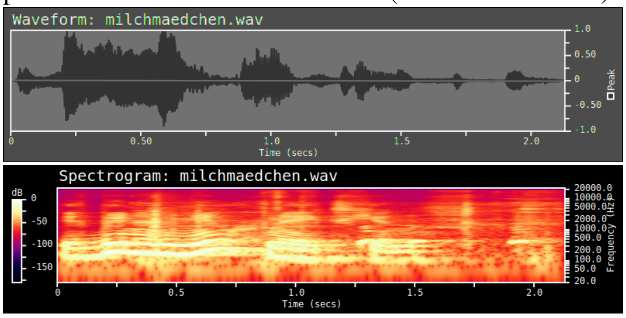
[1] Some of the earliest examples of digital music may have been distributed as code listings on printed paper

lected for its semantic content, the presence of unvoiced and voiced material and the somewhat common speech melody of the speakers.



Listen to unberuehrte.mp3 online.

A second source file is `milchmaedchen.wav` (2.13 seconds) in which a male voice is speaking the german phrase "Ich bin ein Milchmädchen" ("I am a milkmaid.").



Listen to milchmaedchen.mp3 online.

4.2 Transformation steps

The audio file `unberuehrte.wav` is time-stretched and has its partials sustained by accumulation before it is subjected to a bank of time-varying resonant filters. The result is then chopped up into quasi-periodic chunks are each reversed in time.

The second audio file `milchmaedchen.wav` is changed to half-speed and a noisy, percussive and initially unintended trailing sound is extracted and reverberated.

Each of these transformations is iteratively described next, with hyperlinks pointing to the respective mp3 versions of the resulting audio files.

4.2.1 Spectral time stretch and accumulation

The audio file is converted to a spectral domain file (.ana) using the default window of 1024 samples and overlap 3:

```
pvoc anal 1 unberuehrte.wav unberuehrte.ana
```

Spectral time stretching with a factor `30` is applied, resulting in a file lasting 1 minute 14 seconds:

```
stretch time 1 unberuehrte.ana
  unberuehrte-stretch30.ana 30
```

Listen to unberuehrte-stretch30.mp3 online.

Energy in each frequency bin is sustained by *spectral accumulation*

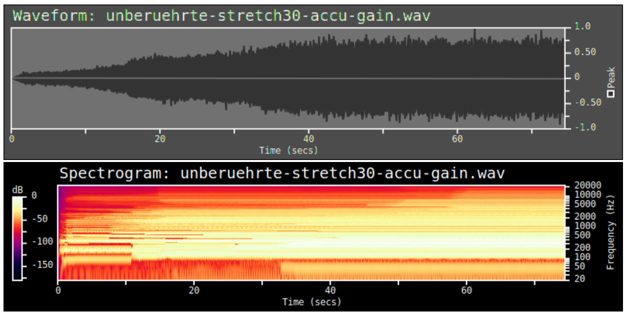
```
focus accu
  unberuehrte-stretch30-gain.ana
  unberuehrte-stretch30-accu.ana
```

and converted back to the time domain:

```
pvoc synth unberuehrte-stretch30-accu.ana
  unberuehrte-stretch30-accu.wav
```

This conversion will report a necessary gain factor of `0.388423` to prevent signal clipping, which is applied to the spectral file before the conversion to time domain:

```
spec gain unberuehrte-stretch30.ana
  unberuehrte-stretch30-gain.ana 0.388423
pvoc synth
  unberuehrte-stretch30-accu-gain.ana
  unberuehrte-stretch30-accu-gain.wav
```



Listen to unberuehrte-stretch30-accu-gain.mp3 online.

4.2.2 Time-varying resonant bandpass filters

A bank of time-varying resonant bandpass filters is overlaid, first querying the sound file duration

```
sfprops unberuehrte-stretch30-gain-accuN.wav
```

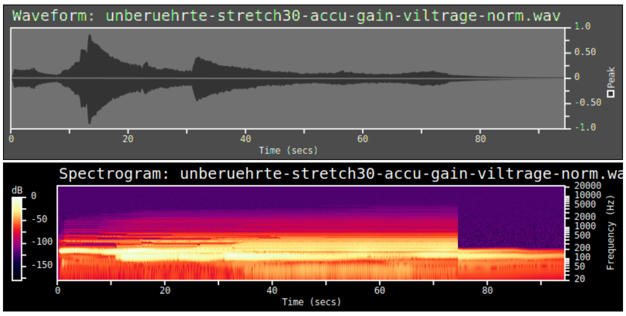
and adding 20 seconds allowing for a sufficiently long filter resonance, resulting in a new duration of 94.4461 seconds. The text file `viltrage.txt` is generated automatically, holding four column pairs of time and frequency values over the `94.4461` seconds for `4` resonant filters having pitches from `28` to `63` linearly distributed `1`, randomized `0.5`, minimum amplitude `0.5`, amplitudes distributed decreasing with pitch `-1` every `4` seconds and times randomized `0.5`. A random seed `-s123` is specified[2] to allow for identical random values on repeated runs of the command:

```
filtrage filtrage 2 viltrage.txt
  94.4461 4 28 63 1 0.5 0.5 0 -1 4 0.5 -s123
```

A bank of resonant bandpass filters controlled by `viltrage.txt` with a very steep and resonating Q of `3000`, a large makeup gain factor `500` and added tail of `-t20` seconds is applied, followed by gain normalization:

```
filter varibank 2
  unberuehrte-stretch30-accu-gain.wav
  unberuehrte-stretch30-accu-gain-viltrage.wav
  viltrage.txt 3000 500 -t20
modify loudness 3
  unberuehrte-stretch30[...]viltrage.wav
  unberuehrte-stretch30[...]viltrage-norm.wav
```

[2] The viltrage.txt used for the published version of this composition was created without a seed value and can hence not be recreated here.



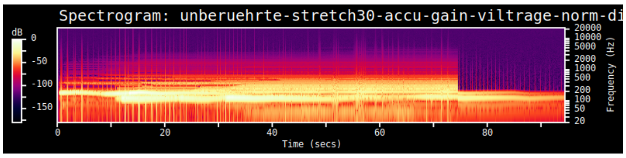
Listen to unberuehrte-stretch30-accu-gain-viltrage-norm.mp3 online.

4.2.3 *Reversal of wavesets*

Every `30` wavesets are reversed as a group, with a waveset being the time section of the signal between three successive zero crossings [25], similar but not necessarily identical to a wavecycle:

```
distort reverse
  unberuehrte-[...]viltrage-norm.wav
  unberuehrte-[...]viltrage-norm-distRvs30.wav
  30
```

The amplitude waveform for the file created does not show any significant change but its spectrogram does. It indicates the onsets of the reversed groups of wavesets, which are in fact discontinuities or impulses with a short broadband spectrum.



Listen to unberuehrte-stretch30-accu-gain-viltrage-norm-distRvs30.mp3 online.

Variations of this transformations are produced, re-using the above command with slower pulsations of `50`, `100`, `125` and `300` wavesets, following the same output file naming scheme.

4.2.4 *Slowing down playback speed and cutting*

The file `milchmaedchen.wav` is slowed down to half speed and hence 4.26s duration:

```
modify speed 1 milchmaedchen.wav
  milchmaedchen-speed05.wav 0.5
```

Listen to milchmaedchen-speed05.mp3 online.

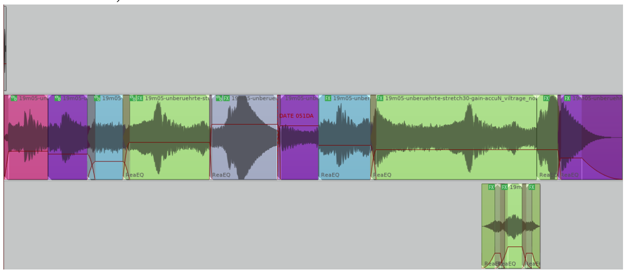
A soft percussive trailing sound is extracted by cutting out a section from `3.104` to `3.788` seconds, followed by gain normalization:

```
sfedit cut 1 milchmaedchen-speed05.wav
  milchmaedchen-speed05-cut.wav 3.104 3.788
modify loudness 3
  milchmaedchen-speed05-cut.wav
  milchmaedchen-speed05-cut-norm.wav
```

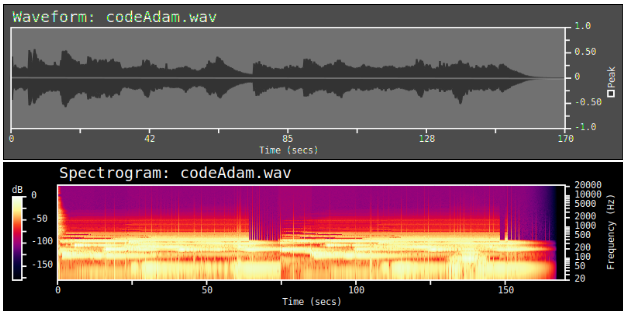
Listen to milchmaedchen-speed05-cut-norm.mp3 online.

4.2.5 *Assemblage*

All files are renamed for better readability, showing only the last transformation affix. The files are assembled in a three track timeline observing the values from the edit decision list in Figure 1. Following the `Position` in the timeline, the `Start` and `Length` values therein indicate the time portion that is used out of that file. All values are in seconds, while `Gain` is in dBFS.



Artificial reverberation with a long reverb tail is added to track 1 holding `milchmaedchen-cut.wav`. Cosmetic EQ is applied to all `unberuehrte...` files on track 2, reducing resonances at 122, 200 and 250Hz and slightly amplifying high frequency content in a wide band centered at 846Hz. The three `unberuehrte...` files on track 3 shifted by -24 semitones in pitch to create a low-frequency layer.



Listen to the published version of codeAdam.mp3 online.

5. DISCUSSION

Several challenges do exist in the creation of iterative scores. All random procedures have to allow the specification of numerical seed values for repeatable results. Although the differences of unseeded random procedures might not be immediately audible, they might nevertheless cause a radically different result when subjected to subsequent sound transformations. The assemblage of sound files on multiple tracks in a time line can be comfortably done inside a DAW but has to be exported as an edit decision list containing only a subset of information for the iterative score. Although CDP offers powerful text-based mixing functions, they were not employed here due to their rather complex usage.

An iterative score will produce many advantages, some of them unexpected. Its documentary approach allows the composer to re-use proven sound transformation techniques in other pieces and access a summarized work diary including sound examples. As such, the iterative score outperforms the undo history of the digital audio workstation,

Track	File	Position	Start	Length	FadeIn	FadeOut	Gain
1	milchmaedchen-cut.wav	0	0	0.684	0	0	-3.806
2	unberuehrte-distRvrs200.wav	0.161	10.713	11.812	1.145	0.013	1.981
2	unberuehrte-distRvrs125.wav	11.961	22.526	12.688	0.013	2.12	1.012
2	unberuehrte-distRvrs100.wav	22.53	33.033	11.48	2.12	1.88	3.257
2	unberuehrte-distRvrs50.wav	32.13	42.642	24.14	1.88	0.677	2.73
2	unberuehrte-distRvrs30.wav	55.592	66.144	19.176	0.677	0.957	3.268
2	unberuehrte-distRvrs125.wav	73.946	0	11.101	0.957	0.092	7.404
2	unberuehrte-distRvrs100.wav	84.955	11.097	15.646	0.092	1.566	3.592
2	unberuehrte-distRvrs50.wav	99.035	25.52	44.942	1.566	0.019	2.339
2	unberuehrte-distRvrs50.wav	143.959	70.444	6.58	0.014	0.95	2.339
2	unberuehrte-distRvrs125.wav	149.59	73.303	17.507	0.95	10.9	-0.429
3	unberuehrte-distRvrs50.wav	129.055	55.54	6.193	3.541	1.171	-3.417
3	unberuehrte-distRvrs50.wav	132.6	59.085	10.046	3.541	2.677	-0.392
3	unberuehrte-distRvrs50.wav	140.074	66.559	4.788	1.059	2.055	-3.417

Figure 1. Edit decision list used in the assemblage.

which contains all actions, but not necessarily all decisions taken. [3] The score presented here furthermore poses an *open source score*, guaranteeing a certain longevity of a work as well as independence from commercial software. When published, iterative scores are of great value in analysis and education. For such a knowledge transfer to work, it is required that the artist lays open part of her way of working, which might not appeal to every composer. The example of an iterative score in this case study documents a rather straightforward way of composing electroacoustic music, with an advance creation of sound material by transforming digital audio files, a selection from these results and their arrangement on a time line on multiple audio tracks. Such a way of working is by no means representative of the plethora of strategies that are followed consciously, or unconsciously, by composers. Other strategies might feature a repeated back and forth between the generation of material and its selection and arrangement in a more circular composition path. Furthermore, time-varying parameters are not featured in the above example. Although technically possible with breakpoint text files in CDP, they result in a large amount of text data, especially when automation curves are entered with a haptic fader interface.

6. CONCLUSIONS

The approach towards a prescriptive as well as descriptive score presented here draws from a subtractive notion towards problem solving using technology [26]. Discarding the graphical user interface and computer mouse will permit the edition of a human-readable iterative score. Such a score constitutes a meaningful textual documentation, especially when provided with additional comments by the composer, and features enhanced accessibility for visually impaired individuals. The iterative score, as a simple text document, is robust to changes in digital file formats, to patent issues and the availability of commercial software. It furthermore opens up new possibilities for an analysis and re-interpretation of digital sound compositions by other artists.

[3] For example. an undo history might record three subsequent gain changes of +5, -3 and +2dB, but will not indicate that the overall level has been raised by 4dB.

7. REFERENCES

[1] R. Wehinger, *Ligeti Artikulation. Hörpartitur*. B. Schott's Söhne, 1970, Reprint.

[2] J.-C. Thomas, P. Mion, and J.-J. Nattiez, *L'envers d'une œuvre. De Natura Sonorum de Bernard Parmegiani*. INA-GRM, Buchet/Chastel, 1982.

[3] P. Couprie, "Methods and tools for transcribing electroacoustic music," *Technologies for Music Notation and Representation (TENOR)*, pp. 7–16, 2018.

[4] A. S. Bregman, *Auditory scene analysis: The perceptual organization of sound*. MIT press, 1994.

[5] H. Eimert, F. Enkel, and K. Stockhausen, "Fragen der Notation Elektronischer Musik," *Technische Hausmitteilungen des Nordwestdeutschen Rundfunks*, vol. 6, no. 1/2, pp. 52–54, 1954.

[6] R. Kostelanetz, *Conversing with Cage*, 2nd ed. Routledge, 1987,2003.

[7] T. Erbe, "The Computer Realization of John Cage's *Williams Mix*," *Proceedings of the International Computer Music Conference*, pp. 154–158, 2016.

[8] L. Austin and M. Thompson, "Williams [re]Mix[er]: An Interactive I Ching Composing Program," in *Proceedings of the International Computer Music Conference*, 2001.

[9] T. Wishart, "The Composition of "Vox-5"," *Computer Music Journal*, vol. 12, no. 4, pp. 21–27, 1988.

[10] T. Wishart, *Red bird, A document*, Music score, U. of York Music Press, Ed., 1997.

[11] T. Wishart, "Sonic composition in *Tongues of Fire*," *Computer Music Journal*, vol. 24, no. 2, pp. 22–30, 2020.

[12] M. Clarke, F. Dufeu, and P. Manning, *Inside Computer Music*. Oxford University Press, 2020. Accessed: Jan. 14, 2026. [Online]. Available: https://pure.hud.ac.uk/en/datasets/inside-computer-music-accompanying-software/.

[13] R. Henke, "Computermusik im Zeitalter des 'infinite undo'," in *Techno-Visionen*. Folio Verlag, 2002.

[14] P. Théberge, *Any Sound you can imagine. Making Music / Consuming Technology*. Wesleyan University Press, 1997.

[15] O. Baudouin, "A Reconstruction of Stria," *Computer Music Journal*, vol. 31, no. 3, 2007.

[16] J. Rohrhuber, A. de Campo, and R. Wieser, "Algorithms today, Notes on language design for just in time programming," in *International Computer Music Conference*, 2005, p. 291.

[17] N. Schnell and M. Battier, "Introducing composed instruments, technical and musicological implications," in *Proceedings of the 2002 conference on New Interfaces for Musical Expression*, 2002.

[18] P. Plessas and G. Boutard, "Transmission et interprétation de l'instrument électronique composé," *Actes des Journées Informatiques Musicale 2015, Montréal*, 2015.

[19] Celemony Software GmbH. "10 years of ARA Audio Random Access," Accessed: Mar. 27, 2026. [Online]. Available: https://www.celemony.com/en/10-years-of-ara.

[20] J.-C. Risset, "Composing in real-time?" *Contemporary Music Review*, vol. 18, no. 3, 1999.

[21] Composers Desktop Project. "CDP History: An Evolving Project," Accessed: Jan. 21, 2026. [Online]. Available: https://www.composersdesktop.com/history.html.

[22] The SoX community. "SoX - Sound eXchange," Accessed: Jan. 22, 2026. [Online]. Available: https://sourceforge.net/projects/sox/.

[23] W. Murch, *In the blink of an eye*. Silman-James Press, 2001.

[24] G. A. Miller, "The magical number seven, plus or minus two: Some limits on our capacity for processing information.," *Psychological review*, vol. 63, no. 2, p. 81, 1956.

[25] T. Wishart, *Audible Design*. Orpheus the Pantomime Ltd., 1994.

[26] G. S. Adams, B. A. Converse, A. H. Hales, and L. E. Klotz, "People systematically overlook subtractive changes," *Nature*, vol. 592, no. 7853, pp. 258–261, 2021.