

# ITERATIVE SCORE FOR DIGITAL SOUND COMPOSITION

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## 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 an example composition are given, 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 usually differentiated between prescriptive and descriptive scores. Prescriptive scores give partial or full instructions to realize a given work. Descriptive scores may employ visual representations [1] and inventories and supplementing texts [2] for analyses and informed listening. 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.

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## 2. SCORES IN ELECTROACOUSTIC MUSIC

Prescriptive scores for the realization of electroacoustic music onto a recording medium do 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 audible result with the original and written intentions may have been loose in such cases but these scores do additionally 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 which variations are the result of unintentional influences of the technology used, and which are the result of choice and taste. Prescriptive scores may alternatively 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.

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. The digital workflow in turn 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 [6]. 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* [7].

Realization scores in form of pure software code are often targeted at works predominantly realized with sound synthesis and some of the earliest examples of digital music may have been distributed as code listings on paper. 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. Such scores are self-sufficient without any additional audio data provided [8]. When well documented with comments and explanations, synthesis code may furthermore allow the study and inspection by a human reader. Software that permits the performance of music by live coding may furthermore permit the tracking and playback of all text input

by means of a history file [9]. Modifications to electroacoustic instruments that constitute *composed instruments* [10], can be considered as an interpretation by their players, either in advance or during a musical performance [11].

For sound compositions in the tradition of acousmatic music, which use audio recordings as their primary source material, a realization score is generally more difficult to furnish. This is especially—and paradoxically—the case when a musical work is created inside 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 by real-time audio effect plug-ins. While real-time processing using plug-ins is the de facto way of working with recorded sound in a DAW, it poses the limitation of not being able to run faster than real-time and has no access to the entire length of audio signal due to its block-wise processing. Not being able to access the entire length of an audio recording in one step is a drawback to most electroacoustic composers wanting to redesign the time axis of a recording. The Audio Random Access (ARA) extension [12] to existing audio plugin standards permits such access, but may be limited to return processed material of the same duration and have a different implementation across different DAWs. Despite the obvious advantages of real-time operation, composition has been outlined as being essentially a non-real-time process in literature [13].

John Cage’s “Williams Mix” (1951-53) constitutes an early realization score for an octophonic tape composition using recorded sound. Indicating edit points for magnetic tape regardless of the tape’s actual content, it was derived from random procedures and does not prescribe a single specific source material. As such, its score does not track the composers stepwise decision making path with regard to the recorded sound but rather exposes these decisions to stochastics. Automated implementations for *Williams Mix* have been created by others [14][15] allowing an easy exchange of the source sound material. The instructions for “Williams Mix” invite individuals to realize a new rendition of the piece with original sound material but do not allow the recreation or alteration of the composer’s initial version.

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 [16][17][18]. A digital resource in [19], covering his work “Imago” (2002), includes references to the actual implementation of the sound transformations and the assembly of the sounds into larger structures while also providing the actual sound files for study.

### 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 can 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) [20], Sound Exchange (SoX) [21] 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) permits a standardized and modular interface to multiple sound transformation programs as well as to powerful file system operations. The most important CLI feature however is the built-in code history and its ability to export a list of all commands entered into a text file, which can then be redacted to yield the steps of an iterative score. These steps will then allow repeatable realizations, identical or very close 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 an 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* [22], which did not make it into the finished piece, but which were possibly necessary to arrive at the accepted edits, are not taken into account. 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 the individual to inspect all the intermediate results of the sound transformations and to alter their technical parameters, scrutinizing their impact on the final sound material.

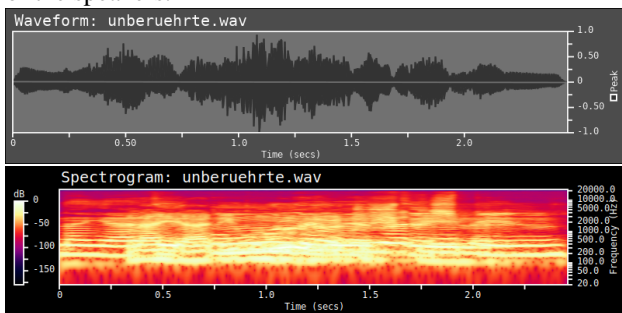
## 4. EXAMPLE

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 [23]. 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 “5. Code Adam” of the composition, the iterative score is presented next.

### 4.1 Source material

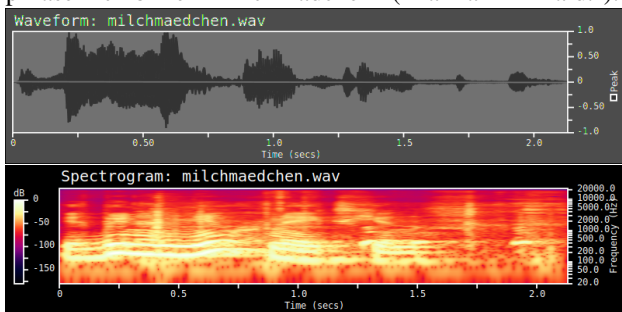
The source material is the mono file `unberuehrte.wav` (2.46 seconds), in which several male and female voices

speak the german words “... die Unberührte spielen.” (“... playing the pristine.”) together. This recording has been selected 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 and 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*

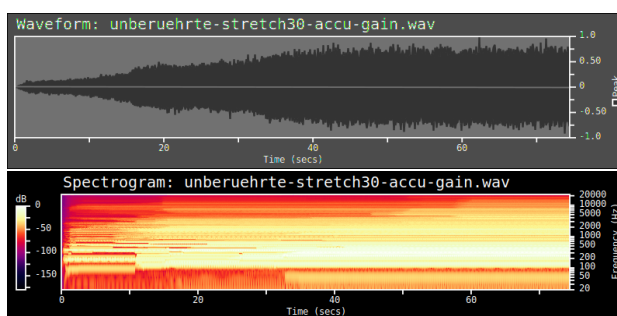
```
focus accu
unberuehrte-stretch30-gain.ana
unberuehrte-stretch30-accu.ana
```

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
```

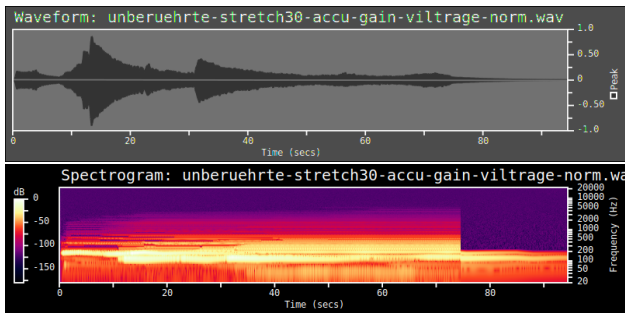
and adding 20 seconds allowing for a sufficiently long filter resonance, resulting in a new duration of 94.4461 seconds. The text file `viltrage.txt` is generated automatically, holding four column pairs of time and frequency values over the 94.4461 seconds for 4 resonant filters having pitches from 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<sup>1</sup> 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 make-up 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
```

<sup>1</sup> The `viltrage.txt` used for the published version of this composition was created without a seed value and can hence not be recreated here.



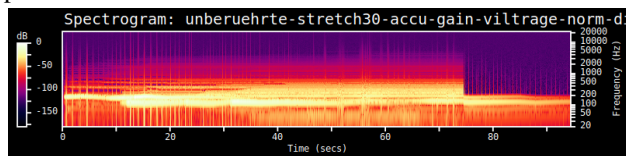
Listen to [unberuehrte-stretch30-accu-gain-viltrage-norm.mp3](#) online.

#### 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 [24], 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.

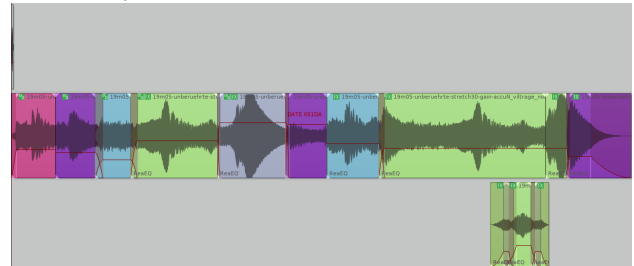
A soft percussive trailing sound is extracted by cutting out a section from 3.104 to 3.788 seconds, followed by gain normalization:

```
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
```

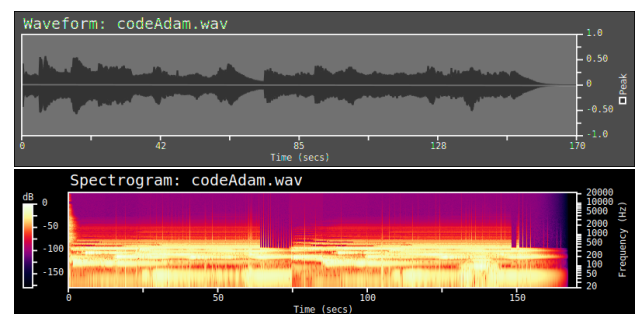
Listen to [milchmaedchen-speed05-cut-norm.mp3](#) online.

#### 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 an iterative score. First, 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 in time on multiple tracks 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. Nevertheless, CDP offers powerful but complex text-based mixing functions, which were not employed here.

An iterative score will as well 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, which contains all actions, but not necessarily all decisions

| 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.

taken.<sup>2</sup> The score presented here poses an *open source score*, guaranteeing a certain longevity of a work and independence from commercial software. When published, iterative scores are of great value in analysis and education. The interested individual gets access to the material and technical parameters and may research their influence on specific steps as well as on the overall outcome of the piece. For such a knowledge transfer to work, it is required that the composer lays open part of her way of working, which might not appeal to everyone. The example of an iterative score presented here documents a rather straightforward way of composing electroacoustic music, with an advance creation of sound material by transforming digital audio files, the selection from these results and their arrangement in time 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 include 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 will 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 [25]. 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 is in large parts accessible by 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.

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

It furthermore opens up new possibilities for an analysis and re-interpretation of digital sound compositions by other artists.

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