"TIME-VARYING SOUND SIGNALS (SONICITY)"

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From within technological signal transduction and data processing, there is no "sound", neither "image"; abandoning with such categories would be warranted in radical media archaeological analysis. So-called "audio-visual" media can be reformulated, from within the technical view, as time-varying (part A) and space-varying (part B) signal processing, indeed. For ensembles like "radio" and "television", though, the bias of its techno-logical "individuations" (Simondon) can only be explained by their technical "intentionality" (Husserl) towards addressing the human auditory and visual sense perception. Techno-conceptual terms like phocity, sonicity, and iconicity are therefore proposed to embrace both approaches, the media-phenomenological and the non-human, technological one.

SONIC "PRESENCING" AND TECHNOLOGICAL VOICING OF THE PAST

Analysis of the "sonic"

"But what is a historic present if not a present that can be successfully archived?"¹ What has not been recordable in alphabetic writing (even if symbolically intended but the explicit introduction of single letters representing vowels in the early Greek alphabet) is the physics of the voice which can be recorded only in the gramophonic signal. "What defies literary memory is approachable only by means of nonliterary media."²

¹ Doane 2002: 105
² Pinchevski 2012: 156
While the present has been considered an inevitably ephemeral, uncapturable time momentum for the longest time, the human voice especially has embodied and allegorized this "fugit tempus" experience of presence. An early newspaper article announcing the invention of the gramophone disc by Emile Berliner starts with the remark that volatile speech has finally been "imprisoned" by the new recording technology, making it not only repeatable for aesthetic or bureaucratic use, but accessible to scientific speech analysis on a micro-level of formation which - different from the human physiological options of memorizing delayed presence - only measuring media can capture, register and thus keep for time axis manipulations. On the darker side of this widening of research topics for humans, with this option goes the traumatic experience that the voice can be preserved as a "dis-embodied" event. Thus it has got into the focus of communication engineering, psychoanalytic and historiographical analysis, particularly in its capacity to engender a sense of heightened presence (as compared with written records).

Audio signal archives emanate from chrono-technical recordings; their specific feature is the power of "re-presencing" (Vivian Sobchack) the sonic event. Sonicity affects and irritates human time consciousness.

**Husserlean and Aristotelean time: Sonic "rhythmograms" vs. discrete clocking**

Sound being understood as time signal event opens access to a plurality of nonnarrative temporalities which even subverts the apparent cultural-historical context of sound perception, production and consumption.

An early advertising for the Bulova Accutron Space View watch announced "The Tick vs. the HUM". But even if "the hum" sound is smoothly "analogue", and thereby coincides with human world experience and the notion of the "flow of time", the mechanical "tick" is (as remarked by Fourier) just an extreme discretisation of the very same vibrant event.

While it has been electronic tools that enabled the investigation of the memory function in the human brain, such as functional Magnetic Resonance Imaging (fMRI) which monitors brain areal activity of experimental subjects, an alternative to neuroimaging is the sonification approach, by parameter mapping, since the sonic access, based on time signals, is closer to the dynamical unfolding and re-assembling of "memories" which do not have a fixed locus in the human brain. The rhythms which structure perception in the human brain cannot immediately be consciously perceived. Therefore a direct sonification of alpha waves in the brain is required. Subjective time sensation occurs apart from the "clocked" time of the Newtonean universe (for classical

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3 For a discussion of Janet Cardiff's audio walk *Her Long Black Hair* (2004) as aural re-presencing, see Barker 2012: 20
5 "[...] nehmen wir diese messbaren Signale mit keinem unserer Sinne wahr": Hinterberger 2005: 284
physics) and "breaking news" (in broadcasting media). Media archaeology as method couples Husserl's diagnosis tightly with technological and archival knowledge. "Data Retention" in fact is a term precisely known from static storage within the computer to ensure that the data in an elementary cell will not be altered. The Static Random Access Memory (SRAM) must be supplied by a power supply that will not fluctuate beyond plus or minus five to ten percent, in order not to disturb the elementary cell and to ensure that it will correctly keep the data. "In that case, the SRAM is set to a retention mode when the power supply is lowered, and the part is not longer accessible."6

The central terms in the Husserlean phenomenology of the "inner" time sense, retention and protention, is subjective in an objective way: both neurologically, technologically and epistemologically. Predictive calculation has been the central temporal figure which gave birth to what was soon to become popular under the name of "cybernetics" which, as the eponymous Norbert Wiener frankly admitted in the introduction to his seminal Cybernetics of 1948, originated in the necessity of World War II anti-aircraft artillery to anticipate the immediate future moves of enemy planes for computing the point in space and time where both the anti-aircraft gunshots and the enemy aircraft meet: "[...] that missile and target may come together in space at some time in the future."7 This mathematics becomes media technology with the necessary implementation of pre-emptive calculation into a servo-mechanism which performs negative feedback correction of its on-going positioning of the artillery gun in real-time. Wiener describes the "mechanico-electrical system which was designed to usurp a specifically human function - [...] the execution of a complicated pattern of computation [...] the forecasting of the future".8 This "window of the present" is time-critical in its most deadly sense and thereby does not that much refer to "live" transmission of radio signals but rather to "life" in its limited time span in combat. Together with Julian Bigelow, Wiener was involved in the "investigation of the theory of predicitions and of the construction of apparatus to embody these theories".9

There is a specific "sonic" temporal quality of the present which is always already instantaneously transforming passing (French passer) into past (French: passé). Only with phonographic recording, such a presence becomes repeatable, thus an experience of enduring presence. The age of storability of voice and sound has already created its very retro-action: Sergiu Celibidache as concert director was radically opposed to phonographic "conservation" of music; he favoured the "now".10

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7 Norbert Wiener, Cybernetics, or: Control and Communication in the Animal and the Machine, Paris (Hermann) et al. 1948, 11  
8 Wiener 1948: 13  
9 Norbert Wiener, Cybernetics. Or control and communication in the animal and the machine, Paris (Hermann) et al. 1948: 13; see Rainer C. Becker, Black Box Computer. Zur Wissensgeschichte einer universellen kybernetischen Maschine, Bielefeld (transcript) 2012, 226  
10 Thilo Hinterberger, Kommunikation mit Signalen aus dem Gehirn, in: Barbara Könches / Peter Weibel (eds.), unSichtbares. Algorithmen als Schnittstellen
The alternative to acoustic communication in terms of periodic propagation of continuous waves, is the "digital", discretizing approach in reverse: addressing the signal components in their frequency value, which makes wave forms countable. Such an analysis re-invents the Aristotelean definition of "time" in book IV of his *Physics* (219b 1-2): *touto gar estin ho chronos, arithmos kineses kata to proteron kai hysteron*.

Frequency *versus* oscillation recalls "duration" in Bergson's sense. There is a remarkable "timelessness" (the Nietzschen "eternal return of the same") in periodic processes which can be addressed as frequencies, as demonstrated with one's perception of the movement of a pendulum clock. When visually following the dial of a clock, nothing is left of the past positions.

A tuning fork, coupled to an electro-magnetic coil (as developed by Hermann von Helmholtz in reverse functionality as electro-mechanic device to measure the micro-temporal run time of nerve impulses), provides the time base in the Bulova *Acutron* watch. The stroboscopic microscope is able to visualize the movements of a tuning fork-based clock developed by the Bulova company.

"The kind [sc. of clocks] that tick work on balance wheels, hairsprings and wachtworks. And that's what can make them work wrong. The Accutron timepiece [...] hums. (Musically, between E and F but above Middle C). Accutron operentes on the precice vibrations of an electronic-powered tuning fork. Each vibration splits the seconds into 360 equal parts and Bulova can guarantee accuracy to within on eminute a month. That's am average pf 2 seconds a day."

In digital computing, this is matched by the Japanese *Parametron* based on resonant circuits. A sine tone here serves as time-giving media event - not for acoustical or even musical sake, but in implicit sonicity: the tempor(e)ality of sound which is shared by processual technologies. The second-indicator does not visibly move abruptly like in the escapement-driven mechanical clock, but almost moves continuously - just like above the haring threshold of ca. 20 hz the human mind can not discriminate between discrete acoustic impulses any more but perceives a continuous tone, even it this tone still consists of oscillating waves (sine / cosine, discretely passing the "Nullpunkt"). Here, two kind of realities overlap: the media-archaeological and the phenomenological one.

**Electronic media tempor(e)ality: "acoustic space" (McLuhan)**

The wall painting *Pied Pipers All* (1969), created by René Cera for McLuhan's seminar room at the university campus in Toronto, in an almost psychedelic manner unreveals the television image as an implicitly sonic event. On the
figurative level, the line-wise unfolding of an electronic TV (half-)frame is linear in the phonographic sense (John Logie Baird's "Phonovision", Bill Viola's "Sound of One-Line Scanning"), while in terms of the sublime ground (broadcasting by electro-magnetic waves), whatever becomes apparent as visual content on the TV tube, the tempo-real message of electronic media is "acoustic" in McLuhan's sense of a simultaneous chronosphere.15

[According to McLuhan, different from "typographic man", in electronic communication there is "acoustic space". For the age of electricity, McLuhan identifies a return of the primordial (oral language-based) "tacility" in terms of the temporal moment with its decisive criterium being its (almost) instantaneous speed of transmission.16]

The sonic is understood here not in its manifest acoustic sense, but as processual ground, thereby akin to electro-magnetic oscillations. Acoustic space is simultaneous and superimposed instead of time-linear, and above all, it resonates: "Resonance is the mode of acoustic space."17 Through resonance in a physical - not symbolically coded - system, micro-events can cause distant objects to communicate - close to time-tunneling and Tesla-like energy transfer.

Sound is not just mechanical attacks, vibrations to the ear or aesthetic pleasure for the brain but addressing the human (pseudo-)sense of temporality. The true message of sound as event is processual time. There is no actual organ for the "sense" of time in humans but only substitutes and equivalents like the hearing organ which is most sensitive to micro-temporal changes of pattern and rhythm. The sublime temporal infrastructure of electronic culture (with its de-materialisation and instant signal transmission) has triggered the reentry of the category of "sonic" as vibrational event. Even if it is not accessible as acoustic content in human perception, its essential message (its simplicit sonicity) is its temporal form.

The remarkable affinity between sonic temporality and frequency-based technical media time is rooted in time-critical moments: First on the level of sonic performance and technological operativity, and second in the a-historic momentum of experiencing time in listening and in experiencing presence-generating devices (chrono-phenomenological aisthesis).18 Sound is transient. German verklingen expresses the dying-out of sonic events ("unsounding").

14 For a colour reproduction see fig. 3 in: Peter Bexte, xxx, in: Derrick de Kerckhove / Martina Leeker / Kerstin Schmidt (eds.), McLuhan neu lesen, Bielefeld (transcript) 2008, 323-xxx (331); http://www.greatpast.utoronto.ca/GalleryOfImages/VirtualMuseumArtifacts/PiedPipers.asp, accessed September 2nd, 2014
Musical articulation always had to take place in time, as a temporal unfolding; even John Cage's composition for piano 4'33" minutes of silence is chronologically defined (with its first public performance with David Tudor at the piano counting time without playing any tone).\textsuperscript{19} In a McLuhanite sense, the acoustical channel itself thus becomes the message.

Martin Heidegger's use of terms from the sonosphere does not refer to explicit acoustics (as physical sound event), but rather to the implicit, epistemological meaning. He made use of sonic vocabulary as a substitutional way of expressing the microtemporal structure of the "event" of being.\textsuperscript{20} The "tuning of the world" (as expressed by Murray Schafer in 1977) is a timing of the world as well. What looks physically acoustic is temporal in its subliminal affect. If the "sonic environment" is extended to so-called Hertzian waves as well, electromagnetism turns out as sublime temporality in all ways.

The unfolding of "acoustic space" is not linear, but reverberating. McLuhan once called it "echo land" - which is micro-temporal folding. When taking the metaphor literally, acoustic echo implies delay, the very temporality induced by the medium as channel of signal transfer which once led Aristotle in his treatise \textit{Peri psyches} to deal (media-)philosophically with the "Inbetween" (\textit{to metaxy}). By turning the adverb into a noun, after its translation by medieval scholasticism this became \textit{medium}. Therefore the very term media stems from sonic analysis.

Notwithstanding his confusing electricity and electronics, McLuhan thereby made a crucial discovery about the intrinsically "acoustic" structure of electronic mediascapes which are rather defined by temporal relations to each other than by spatial ones.

The affective immediacy of electricity is the reason for traumatic subliminal effects in human perception; this makes the time-critical difference to the world of traditional print culture which, as McLuhan analyzed in his days already, "[...] is threatened, not by any single factors such as television or radio, but by the electric speed of information movement in general. Electric speed is approximately the speed of light, and this constitutes an information environment that has basically an acoustic structure."\textsuperscript{21}

Acoustic signal presence (wave form) differs from the present digital instant (impulse coded as bit). If signals come simultaneous from all directions this

\begin{itemize}
\item[\textsuperscript{18}] On "the ontology of vibrational force" and "microsonic turbulence": Steve Goodman, Sonic Warfare. Sound, Affect and the Ecology of Fear, Cambridge, Mass. (MIT Press) 2010, 81-84
\item[\textsuperscript{19}] John M. Cage, Silence. Lectures and Writings, xxx (Weleyan University Press) 1961, 8
\end{itemize}
corresponds with the structure in the act of *hearing*. But very media-
archaeologically, McLuhan's identification of the essence of electronic media as
"acoustic structure" evidently refers to an epistemological ground, not to the
acoustic figure of what ears can hear. This ground-breaking took place with the
collapse of Euclidean space into Riemann spaces and culminates around 1900
with quantum physical notions (the para-sonic wave/particle dualism, up to the
"superstring" theory of today) on the one side, and Henri Bergson's dynamic
idea of matter as image in the sense of vibrating waves and frequencies on the
other side. McLuhan's "acoustic space" is oscillating time and implicitly re-
turns in Gilles Deleuze's Leibniz-inspired "interval" philosophy. Less
philosophically, it actually happens within algo-rhythmic media.

Therefore the message of the sonic is not limited to the audible at all, but a
mode of revealing modalities of temporal processuality - which requires media-
archaeological auscultation like with an epistemological stethoscope.

But the digitally modulated (PCM) electrosphere of today differs from this
radiosonic (AM) metaphor; its musicality consists of rhythmic impulses rather
than continuous waves. With digital numbers, central characteristics of what
McLuhan diagnosed as the Gutenberg Galaxy of print culture\(^\text{23}\) have returned,
thus bracketing the age of analog electronic (mass) media as a interplay of
modernity. In a dialectic synthesis, mobile digital telecommunication is now
combined with the characteristics of "acoustic space" which is the instant.

According to Marshall McLuhan's *Media Log*, "[s]imultaneity is related to
telegraph, as the telegraph to math and physics."\(^\text{24}\) But this discrete
simultaneity is of a different kind. The Internet consists of techno-mathematical
topologies rather than electromagnetic waves (even if the electromagnetic
sphere survives as channel of wireless data transmission). "Now, Internet
'radio' isn't radio; it does not exploit the spectrum, and that is a big
difference"\(^\text{25}\) - just like the difference between recording in vinyl grooves and its
Compact Disc inscription where its close analysis reveals bit streams which
allow for information theory, thereby: mathematical intelligence to control the
event of signal storage and transmission. This happens in sublime manipulation
on the micro-temporal level. Even if according to the Nyquist / Shannon
Sampling Theorem human perception might not even notice the difference
between a high definition analog television image and its digital equivalent,
ontologically this image has transformed into a different time-object once the
critical perspective of the "receiver" is not humans but technologies
themselves. But digital data processing which absorbs time to calculate always
lags behind live transmission which allows for a different presence.

**„Presence“ in audio technology**

\(^{22}\) Henri Bergson, Matter and Memory, London (George Allen & Unwin) 1950, 276
\(^{23}\) Marshall McLuhan, The Gutenberg Galaxy, Toronto (University of Toronto
Press) 1962
Berlin (in cooperation with Gingko Press) in 2011
\(^{25}\) Davis 1997
By software-based motion tracking it can be micro-analyzed that the performative motion anticipates the actually unfolding tone sequence which corresponds to Husserl's notion of the "time window" of melodic presence in neuronal pro- and retention.\textsuperscript{26}

Different from the originality of a work of art in photographic reproduction (as described by Walter Benjamin), the \textit{aura} of physical sound can remain intact in its essential feature which is temporal integrity even if converted into the digital code. If by physical modelling matter can be algorithmically reproduced, but movement and sonicity - thus not loosing its temp\textit{AURAL} quality.

"Presence" in sound engineering is the term for the degree of clarity in instrumental and vocal sound, which can be increased by use of the Equalizer within the frequency ranges of around 18 Hertz to 16 kHz. "In an amplifier, a presence control controls 'presence'. A presence control boosts the upper mid-range frequencies. Thus by increasing the presence with the presence control, the sounds of voices and such instruments seem more 'present'."\textsuperscript{27} Remarkably, the audio-technical term \textit{presence} is attached to the voice (or instrument) here. The voice is perceived as indexical testimony of presence on the one hand, and its irritation (subverting testimony) on the other when replayed from phonographic recording.\textsuperscript{28}

"On television production studio's sound desk, there can be several presence controls, for several different, switchable, frequencies. [...] If the degree of mismatch between microphones is great, simply increasing presence is not enough, and instead a sound engineer will use a graphic equalizer, sometimes several, each connected to an individual sound channel"\textsuperscript{29} - an operative diagram.

"Presence controls can also be found on electric guitar amplifiers. The first presence control on a Fender amplifier [...] appeared in 1954 on the Twin. [...] The original Fender presence control acted upon the amplifier's negative-feedback loop" (ibid.).

**Signal run-time as acoustic media archaeology**

There is a privileged affinity between "the larger gestalts of auditory temporality"\textsuperscript{30} on the phenomenological level and the processual being of technical media. Here, time-critical moments parallel the most frequency-sensitive ("rhythmic") sense organ within the human which is hearing.

\textsuperscript{26} See Rolf Inge Godøy, Marc Leman (eds.), Musical Gestures. Sound, Movement, and Meaning, London / New York (Routledge) 2010
\textsuperscript{28} See Doris Kolesch / Sybille Krämer, Stimmen im Konzert der Disziplinen, in: same authors (eds.) 2006: 7-15 (7)
\textsuperscript{29} Wikipedia op. cit.
\textsuperscript{30} Don Ihde, Listening and Voice. Phenomenologies of Sound [*1976], Albany, NY (State University of New York) 2007, 87
If a movie camera or projector is driven manually like in the vera early days, it turns out the visual perception is much more tolerant to slight temporal deviations. This is different with auditory signal replay. Let me illustrate this by a short audio-visual argument produced by the Media Archaeologal Fund at Humboldt University:

A symbolic order such as the musical composition, being a conceptual diagram, is ideally invariant towards shifts on the time axis, while the historicity of sounds depend on its material embodiment. "Is the sound of an existing Roman era bell dating from the third century a more ancient sound?", the artistic media archaeologist Paul DeMarinis asks. "For this to be the case we would have to think of the bell itself as an encoding of some 'sound'; that sound, in turn, would have to include the splashing of the molten brass, the beating by smiths' hammers etc. But the sound the bell produces in its current use is far from being a recording of these sounds" - rather co-originary sonic production.31

Phonographic "engraving" on the contrary is sound in latency. The ontological status of recorded sound is waiting to be activated (German "in-Vollzug-Setzung"), that is: to become medium. This corresponds with the Heideggerean "being-in-time". "Heidegger does not mean by essence (Wesen) what something is, but how it comes to presence (wesen, a verb)."32

This can be correlated with the temporal "window of present" of sonic experience which itself corresponds with micro-temporal actions within both primary physics and derived technologies.33 The conflict between the physically impossible ideal sinus wave in Fourier Analysis and its transient momentum as an actually physically performed tone epistemologically resonates.

While traditionally acoustic elements have been symbolically ordered in time ("music"), on the micro-temporal level Fourier analysis identified sound as an event of superimposed (sine) tones itself with its individual frequencies. "Die Trennung 'akustischer Vorordnungen' im Material und 'musikalischer Ordnungen' mit diesem Material müßte dann aufgehoben werden."34

The sonic present

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34 Karlheinz Stockhausen, Die Einheit der musikalischen Zeit, in: Dieter Schnebel (ed.), Karlheinz Stockhausen. Texte zur elektronischen und instrumentalen Musik, Bd. 1, Köln (DuMont) 1963, 211-221 (214)
In electronic epistemology, what looks like a particle is in fact a high frequency motion, mathematically expressed by the wave equation. The concept of micro-tones corresponds with micro-temporalities in the media-archaeological sense. In fact, "tones" are in the frequency realm what is the reverse of a time function (the sonic wave).³⁵

Discrete Cosine-Transformation encodes complex, time- or space-variant signals into a series of discrete frequency components. "They can be added together to reconstitute the original signal during decoding. Nearly all video codecs transform spatially extended images into sets of simple frequencies"³⁶ - a form of implicit "sonification", and thereby time-critical: "This allows them to isolate those components of an image that are most perceptually salient to human eyes" (ibid.). At first glance this "sonification" appears counter-intuitive: "In what way can a videoframe be seen as a waveform?" (ibid.). A notion of implicit sonicity emerges: the emancipation of sound as temporal form from physical acoustics.

"Sound is not static, it is first and foremost vibrations, and secondly it is friction that causes sound to be heard"³⁷ - the friction between different physical elements. This is actually embodied in the piezo-electric effekt, when a voltage is applied to a crystalline surface and induces a shock wave.

In McLuhan's sense, "acoustic space" - beyond the age of printed knowledge - is characterized by its non-fixity - "[v]ersatile and vibrating thoughts that do not rest to stay [...]." High-technological media share with sound its mode of existence-in-time: they exist only in sonorous performance respectively technical operativity. Therefore media analysis non-metaphorically applies sonic terms such as echo, resonance, vibrato, reverberation.

Another form of sonicist investigation is "to examine the pauses, the rests, and the silence". Different from cultural poetics and aesthetics (John Cage), technological silence signals a differential articulation. Speaking a silence, or letting silence speak, is practice in communication engineering since telegraphy and type-writing (and printing) with the empty "space" key. In the binary alphabet, the "off" counts as much for information as the "on". Thus speaks media-archaeology.

Micro-archiving sonic presence with technologies

Technical recording of sound is a process of storage. "The breaking of the time constraint has profoundly changed the nature of acoustic communication."³⁸ The temporality (and volatile being-to-death) of sonic articulation which hitherto could only by recorded symbolically by mnemonic notation is transformed into space and visualization by the very act of recording, making it available for analysis "outside of time" (ibid.). The temporal essence of sound is

³⁵ See Curtis Roads, Microsound, Cambridge, Mass. 2004
³⁶ Mackenzie 2008: 51
³⁷ Tisha Mukarji, Auscultation (2009); http://www.sonicthinking.org/auscultation.html; accessed February 16, 2010
³⁸ Barry Truax, Acoustic Communication, Norwood, N. J. (Ablex) 1984, 117
thereby turned into a reified, objectified time object, from evanescence to the ob-scene.

The traditional sound record - like the textual record - can be included within an institutional archival frame. With digital sound, though, literally every bit of sonic articulation becomes part of a generalized "archival presence", since a) every digital signal processing involved ultra-short quasi-archival intermediary storage and b) every sound "bit" becomes numerically addressable and thereby accessible to mathematical, algorithmic manipulation. The archival frame is deconstructed and re-turns from within the digital archival records themselves. From analog to digital "archiving" sonic presence, "the manner of storage determines the kind of control that can be exercised over it" - from manipulation to distortion.\(^{39}\) At the same time, the analog-to-digital conversion results in a transsubstantiation of the audio signal: from the primary physical event to information which is essentially neither energy nor matter. Thereby the signal loses its indexical trace; transitive transduction is therefore to be set into quotation marks: "[...] the digital 'transduction' process includes the digitalization of the analog signal by the ADC, its <micro->storage and / or manipulation in binary number format, and its reconstruction as an analog signal by the DAC\(^ {40}\) - which is the conversion of an electronic representation (embodiment?) of a number stored in the computer memory to discrete voltage steps at fixed time intervals (D\(t\)). The physically continuous original waves are thus transformed into square waves; in fact every binary computational act is an abrupt form of oscillation between zero and one in a time-sequential form. Only by smoothing the square wave by filters the wave becomes continuous again.

Sonic Media Tempor(e)alities: From Analog to Digital

The primal scene (Freudian Urszene) of affective irritation of "presence" has been the moment when the human voice which has represented the most transient articulation of presence for ages (since Plato's criticism of writing until the deconstruction of occidental logo-centrism by Jacques Derrida) phonographically could be stored and re-played even beyond the dead of the voice-bearer. The working assumption of the Berlin Team research is that Edison's invention of 1877 which allowed for not just symbolical (phonetic writing in vocal alphabet) but physical (the acoustic signal) recording of the disembodies individual voice has been a cultural shock which - although it soon became part of everyday sound culture - has still not been digested within the cultural unconscious. What seems natural to an animal (the notorious dog Nipper listening to "His Master's Voice" at the gramophone tube) for humans leads to a traumatic dissonance between cognitive knowledge (the historicity of the recording) and neuro-physiological affect which perceived the gramophonic voice as pure presence (Dolar).

When in Paris Pierre Schaeffer defined the acousmatic\(^ {41}\) for musique concrète, he re-used a term once coined to describe the teaching method of Pythagoras who concentrated ("heated up", in McLuhan's terms) on the human audio

\(^{39}\) Truax 1984: 119  
\(^{40}\) Truax 1984: 139  
\(^{41}\) Pierre Schaeffer, Traité des objets musicaux, Paris (Seuil) 1966, 91
channel of communication by hiding behind a veil (or in a cave) while speaking. This acoustic purism is truly archaic in the media-archaeological sense: letting the pure, disembodied voice emanate while the sound-generating human or machine is hidden. For the listener it is undecidable whether there is human presence, radio transmission or a gramophone record behind the veil. Thereby the visual absence of the sound source does not only refer to space but to temporal irritation as well. An ongoing (even apparently accommodated) paradigmatic shock took place since the invention of the phonograph (and the answering machine), when all of the sudden the voices of the dead could be heard again in re-play: acousmatics in (flat, close to the present, or deep, "historically" distant) time. In addition, there is an additional micro-temporal dimension of acousmatics. Irritation of acoustic perception takes place even when a corresponding visual source can be noticed but is not synchronized with the acoustic event (well known from problems in lip synchronization in sound film).

The voices and sounds emanating from such a black box are radically bodyless, resulting in a different timing than the symbolical historio-graphical time. This split between an original sound and its electroacoustical recording results in what R. Murray Schafer called "schizophonia" - a dissonance between the affective and the cognitive awareness of sound-based time consciousness.

A special emphasis is put on the analysis of the digitization of "sonic" media archives in its wider sense - with "sonicity" here being used in a neo-logistic way as a category of time-related objects of knowledge, referring to the range of time-based media which are sonic in the sense that electro-mechanical and high-electronic operations share with acoustic events their radical temporal condition. While archives of visual evidence (photography, cinematographic frames) represent a static archive (endurance), the "acoustic space" (McLuhan) of recorded sound and electric circuits stands for processual temporalities. While on the level of user interfaces the digitization of sound sources from the analog archive is mostly unnoticed in the everyday media practice, it is of utmost importance to point out the deep rupture which sublimely takes place when qualities like analog "live" transmission is being replaced by "real time". Such calculations create ultra-short intermediary archives which look like presence in the narrow time window of what physiologically counts as presence. In addition, the authenticity of the indexical signal is challenged once it gets processed digitally. Acoustic experience within that context serves as a privileged field for analysis. Ironically, by analog-to-digital conversion ("sampling") the symbolical code (previously represented by the textual alphabet, or musical notation) returns in mathematical forms (alphanumeric algorithms), asking for a refreshed grammatology of the theory and practice of "archiving presence".

Digital sampling troubles the human ears by making it a player in the sonic imitation game: "Drum or keyboard sounds stored on a digital music computer can be triggered by analogue recordings. [...] a 'real' drummer, playing with human imperfections, can be made to sound like a machine. [...] this technique has been consolidated into a piece of hardware called The Human Clock - a
triggering device that enables a drummer to drive machines in synch, according to a varying human tempo."  

This results in irritations "between human and automated rhythm", culminating in a metaphysics of the analogue: "This sense that analogue is warmer and more natural than digital also extends to its visual signification, [...] signified via the words we use to describe these patterns - waves as opposed to numbers" - or pulses.

While mechanical sound recording directly corresponds with (and to) the mechanical vibrations of the Gusle string and the Guslari voice, magnetic recording requires the intervenence or a literally technical "medium" which is the apparatus of electro-magnetic induction. The wire recorder, by its very recording medium (a steel wire), directly corresponds with the telephone line - thus allowing for a kind of direct transmission of recorded songs from storage to presence: "re-storing presence".

The sonic time sense in humans clearly observes what Roland Barthes has analysed for lightning-like momentum (punctum) of a photography from the past which (notwithstanding its intellectual cognitive studium which refers to its contextualisation in history) rather indexially (the chemical fixation of light traces) than metonymically (rhetorical narrative) links the past to the present spectator: "ça a été", the affect of a presence in absence, a kind of negative ontology of presence, resulting in "affective consciousness" when viewing a photography.

**Sound pulses human / inhuman: heart beats**

Media-based figures of time define life as a function of pulsating rhythms. Not the technical frequencies are being evoked (that would be electro-magnetic radar pulses) but human presence as represented by heart beats - imprisoned in many senses. The human heart turns out to be an archetypal case of the acousmatic dispositive; while it can be heard it can not be naturally seen. The chest has to remain closed in order to constitute a space of resonance for the heart beats. In a dissimulative disguise of sonic technologies, non-invasive real-time ultrasound imaging in the medical context renders the phantasmagoric impression of actually "seeing" inside the body, while its visuality is a techno-mathematical transformation of ultra-sonic impulse responses. Appropriately, one of the earliest applications of sonic signal transduction into visual representation has been called Hyperfonografie in 1942 by the neurologist Karl Dussik.

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43 Goodwin 1990: 265

44 Roland Barthes, Camera Lucida, London (Vintage) 1993, 55

What literally "counts" here is neither the sonic event nor its imaging procedure, but the run-time of the signal from which shapes of reflecting matter is computationally derived. The mythic nymph Echo becomes media-archaeologically grounded in echokardiography which is based on the impulse-echo-procedure.

**The sono-traumatic affect**

Presence is no ontological state but an affect of *différance* (Derrida). "Viola's deconstruction of presence leads [...] to the unconscious discovery and experience of time - an essentially traumatic event. [...] This sense of trauma is articulated through the primordial scream that recurs throught Viola's work [...]."\(^46\)

Jonathan Sterne writes on the idea of the resonant (phonography-based) tomb, embalming et al. as the discursive condition which gave rise to sound recording technologies: "Phonographic time was the outgrowth of a culture that had learned to can, to embalm, in order / to 'protect' itself from seemingly inevitable decay."\(^47\) It might be added: this was the epoch of studies in thermodynamic entropy as well. This is the discourse-analytic approach, as expressed in the subtitle of Sterne's monography *The Audible Past: Cultural Origins of Sound Reproduction*. Under this perspective, recorded voices did not result in a shock but resonated with an already established discursive condition. But even if sound recording apparently results from a discursive setting within a socio-historical context, the probability does not explain the qualitative rupture which resulted from the being-there of phonography. Contrary to discursive phantasmogoria, phonography arose from the epistemological desire to analyse acoustic wave forms (Young, Léon-Scott et al.).

Different from hermeneutic understanding (German *Verstehen* resonates with its acoustic hearing) Joseph Carl Robnett Licklider researched to which extent speech can be distorted and still remain intelligible: "Distortion is most easily thought of as a deformation of a function of time or of frequency"\(^48\) on the rather microscopic level.

Only with its implementation in physical vibrations, sound as cognitive or symbolically notated "musical" concept starts to haptically affect the human sense of temporal presence. From this material implementation emanates the power of phonographic sound recording media to "represence" (Vivian

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\(^46\) Donald Kuspit, Bill Viola: Deconstructing Presence, in: Barbara London et al. (Hg.), Bill Viola: Installations and Video Tapes, New York (The Museum of Modern Art) 1987, 73-80 (78)


Sobchack) past performances. Whereas the cinematic format and TV image is always perceived as framed and thus contained (as a kind of distancing quotation mark of reality), the acoustic signal cuts directly, even aggressively into the ear. The radio voice is not perceived as representation of the "real" (physically present) but as identical with the human voice itself.

ASYMMETRIES BETWEEN SONIC SIGNALS AND MUSICAL MEANING

It has been a "first order" cybernetic premise that capacities of the human "mind" (less emphatically than its German equivalent Geist) can be modelled by logical circuitry (McCulloch / Pitts) and by "learning" automata, as has been demonstrated with the "Perceptron" for visual pattern recognition.\(^{49}\) This has been developed into musical information aesthetics, admitting the problem of machine "creation of valuable, meaningful artificial texts, the aptitude to master a general semantics"\(^{50}\), based on the "functionalist" hypothesis that non-biological processing of sensory objects are chrono-structurally equivalent (isomorphous) to what is declared "meaningful" by humans, as expressed, e.g., in Turing's paper "Computing Machinery and Intelligence", or in Gotthard Günther's definition of the "trans-classical machine" consciousness\(^{51}\). If mental states are analogous to computational states, they are multiply analyzable and synthecisibable, even "in electronic states of robots"\(^{52}\). The question of machine meaning has to be preceded by a definition of what is understood as "meaning" - accompanied by the media-archaeological perspective of how the machine looks at human meaning, in reverse simulating artistic creation such as by Markov approximation (Max Bense's radio play Der Monolog der Terry Jo). In the age of Turing tests, there is a persistent, uncanny (if not "traumatic") uncertainty whether the musical meaning arising in humans derives from human or technological composition.

Hermann von Helmholtz' differentiation between physiological acoustic perception ("Wahrnehmung") and musical sensation ("Empfindung") as well as the neuro-aesthetic focus of Systematic Musical Science on musical cognition, remains overtly anthropocentric. Technology-focused Sound Studies, on the contrary, listen to the sonic signal and from there define music as as cultural technique of "organized sound" (Edgar Varèse). With the media-epistemic concept of implicit sonicity as temporal, time-critical form, the notion of "music" does not only make sense for human receivers, but equally refers to the "algorythm" (Miyazaki) of programmed computation.\(^{53}\) There is musical


\(^{50}\) Abraham A. Moles, Cybernetics and the Work of Art [FO 1965], in: Rosen (ed.) 2011, 217-225 (218)

\(^{51}\) Gotthard Günther, Das Bewußtsein der Maschinen. Eine Metaphysik der Kybernetik, Krefeld / Baden-Baden (Agis) 2nd ed. 1963, supplement IV "Die 'zweite' Maschine" 179-203

\(^{52}\) http://www.scholarpedia.org/article/Teleofunctionalism, accessed 5 April, 2018

\(^{53}\) For such a blending of mathematical algorithm with musical rhythm, see Shintaro Myazaki, Algorithmics. Understanding Micro-Temporality in Computational Cultures, online in: Computational Culture, Issue 2 / 2012, http://computationalculture.net
understanding (if not "meaning") within technological systems themselves; radical media archaeology here separates from phenomenology in favor of a techno-processual ontology.

**Against the phenomenological anthropocentrism of discussing musical "meaning"**

Steve Goodman proposes an "ontology of the vibrational force". There is implicit "hearing": "Sonic events – e.g. noises, sounds, music – are not perceived by the ear alone; with other bodily or material sensors, they trigger both physiological and physic reactions. In research of such phenomena, measuring devices, augmented by software intelligence, are the first listeners, first of all; only such technologies provide the means "to better understand and explore these and other affects." The loss of "musical" control of sound by electronic variations is compensated by algorithmic control again. Media archaeological understanding leads to an "epochal" (Husserl), at least temporary disempowerment of the perceiver’s position as the listening subject; human "musical meaning" becomes open to non-hierarchical connections between sonic phenomena. There is the acoustic physical signal, which is perceived as "sonic" within humans by cultural prefiguration, and the musical sensation being semantically charged and temporally ordered. But once "rhythm is wrested from the established notion of measure in music, a perplexing diversity of terms, instruments and practices unfolds, situating it between a manner of flowing (ruthmos) and an order of movement, proportioned figure (metron) [...]." Rhythmic semantic can be derived from automatisms already, like the non-auditory planetary "spheric" music, diagramatically defined by Platon. Aesthetic experience does not come to existence in human perception only.

In an advertising prospectus from 1905, the Freiburg Welte company differentiated between "mechanical music" from its personalized recording technique for reproduction piano "mit allen Feinheiten des rhythmischen und dynamischen Vortrags mit völligem Erfassen der persönlichen Note". Against the human pianist re-enacting "historic" scores, the reverse question arises: Does machinic "interpretation" preserve a different machinic meaning, arising in the dynamics of the machine body? Welte-Mignon reproduction pianos "read" punched information from rolls, pneumatically triggering piano keys. Is the human musicologist or piano player, when reading or playing a score, him/herself in such a machine state, in the sense of the *turingmachine* with its tape-"reader"? Charles Babbage once derived the mechanics for programming

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54 Goodman 2010: 82
55 The Berlin Club Transmediale (CTM) 2015 festival theme *Un Tune* draft; http://www.ctm-festival.de/festival-2015/theme
56 Online draft for the *Rhythm-Expression* discussion of the Berlin festival MaerzMusik, hosted by Bojana Cvejić, Tom Engels and P.A.R.T.S. Research Studios group, with Bernhard Lang. Haus der Berliner Festspiele, 14 March, 2016, within the "Thinking Together" discourse program
his digital Analytical Engine (around 1830) from the Jacquard loom, from textile machines based on "digital", punched card notation. But different from a musical score, such "operative coding of a textile structure", when implemented mechanically, allowed for an instrument to algebraically generate not only repeated but new patterns\textsuperscript{58} - implicitly "musical" algorithms in Ada Lovelaces sense.

Is the cultural phenomenology of "musical meaning" \textit{incommensurable} with technical, that is: non-discursive embodiments of sound as articulation of specific tempor(e)alities? There is an asymmetrical relation between "sound" as signal event and "music" as cultural code - unless, in a technical recursion of the ancient European link between music and mathematics, "digital" media are understood as the truly techno-logical mathematization of sonic matter - and thereby a re-entry of the "musical" structure which is numerical ratios (harmony) and rhythms respectively "algorithmics"\textsuperscript{59}.

\textbf{Time-Critical Analytics}\\

The technological capturing of human "musical" performance (both physiology and cognition) enables not only its machine reproduction and synthesis, but scientific analysis as well. Media archaeologically, the recording apparatus, as has been developed by Welte company in Freiburg for \textit{recording} the dynamics of piano play for replay, correlates with technical devices developed for scientific \textit{measuring} of micro-temporal piano key movements.\textsuperscript{60} As has been experimented by Boris Yankovsky in his Syntonfilm Laboratory in Moscow, once sound has been spectrographically analyzed, it can be re-synthesized, resulting in synthetic acoustics without human source at all, like the Vo(co)der. Such graphical sound extends to manipulations like time-stretching and pitch transposition.\textsuperscript{61} Nikolay Bernstein's "chronocyclography" has been a parallel effort for techno-analytically catching the musical "gesture".\textsuperscript{62} Graphical analysis results in a spatialisation of the sonic time axis. Such a geometrisation of the sonic event deprives it of its essential message which is time, ultimately \textit{logifying} the wave signal into a mathematical, "musical" ratio (\textit{lógos}) instead of

\textsuperscript{58} See Birgit Schneider, Programmierte Bilder. Notationssysteme der Weberei aus dem 17. und 18. Jahrhundert, in: Horst Bredekamp et al. (eds.), Das technische Bild, 2008, 182-190 (189)
\textsuperscript{59} In Shintaro Miyazaki's sense: xxx
\textsuperscript{61} See Smirnov 2013: 209-226
\textsuperscript{62} See Julia Kursell, Moscow Eye and Ear-Control. Über die neurophysiologischen Arbeiten von Nikolaj Bernsteijn zum Klavierspiel, in: Sabine Flach / Margarete Vöhringer (eds.), Ultravision. Zum Wissenschaftsverständnis der Agantgarde, Munich (Fink) 2010, 83-105
its processual acoustic (matter) event.\textsuperscript{63} But when coupled to a machine reading, graphical inscription becomes a musical time-event again. A Chopin score "is not a transcription of a performance; it prescribes how certain performances [...] should be [...] . In this respect, it is more like the circuit diagram an engineer produces for a new electrical component [...] ."\textsuperscript{64} But in electro-diagrammatic reasoning, it is matter itself which interprets the (musico)logical score. In contrast to machine reproduction, human piano play from a historic score is hermeneutising the notation, just like in early nineteenth century, lithographic engraving of historical paintings endured as "critical" form of human reproduction, rivalling the recent visual reproduction medium of photography.\textsuperscript{65}

Oral epic poetry, once fixed on phonographic media like the master recording of a Jazz improvisation, has almost immediately been transcribed for philological (scholars like Milmar Parry and Albert Lord) and musical interpretation into a score for research by Béla Bartók in its time. But from its parallel storage on aluminium disc, wire spool or sound film as signal memory, it can now be techno-mathematically "transcribed" into a score of a different kind, serving Digital (or better: algorithmicised) Humanities, as well as "artistic", research.

The dynamically faithful Welte recording of artistic piano play corresponds with microtiming in the recomposition of past performance practice. Richard Beaudoin, since 2009, composes new, notated, acoustic works based on millisecond-faithful transcriptions of recorded piano performances, applying most refined methods of acoustic microscopy and microtiming.\textsuperscript{66} Interpretation as sonic hermeneutics and as scientific measuring the acoustic event, all of the sudden, are no contradictions any more.\textsuperscript{67}

"Western musical notation has been developed to represent [...] works that require performative interpretation."\textsuperscript{68} The micro-temporal analysis of an actual interpretation of a score by the piano performer has replaced the "philological" interpretation of the written score as \textit{oeuvre} in Western music. By technical inscription for signal measuring, the investigative \textit{lógos} approaches what at first sight seems to escape analysis: the ephemeral sonic articulation. A spectrogram, e. g. of the first 21 seconds of Chopin's \textit{opus} 28/4 in Martha Argerich's 1975 interpretation, created with the Lucerne Audio Recording Analyzer (LARA)\textsuperscript{69}, may be considered a sonoanalytic "photograph" of the

\textsuperscript{63} Hermann Gottschewski, Graphic Analysis of Recorded Interpretation, in: Computing in Musicology vol. 8, 1992, 93-96  
\textsuperscript{64} Beaudoin / Kania: 124  
\textsuperscript{65} See leMan 1994  
\textsuperscript{66} See Richard Beaudoin, The Principles of Microtiming and Musical Photorealism, manuscript http://nrs.harvard.edu/urn-3:HUL.InstRepos:3415685  
\textsuperscript{67} See Heinz von Loesch / Stefan Weinzierl (eds.), Gemessene Interpretation. Computergestützte Aufführungsanalyse im Kreuzverhör der Disziplinen, Mainz et al. (Schott) 2011  
\textsuperscript{68} Beaudoin / Kania: 123  
\textsuperscript{69} See Beaudoin / Kania: 122, Fig. 4: output from the Luzern Audio Recording Analyzer (LARA), showing the millisecond-faithful measurement of four bars of Chopin Op. 28/4 in the recording of Martha Argerich from October 1975
A spectrograph represents *sounds*, or vibrations in the air, but not *music*, which requires perception of a uniquely human sort [...] just as we see three-dimensional objects *in* certain two-dimensional arrangements of pigment.\(^{70}\) Beaudoin therefore manually transferred the spectrographic information back into a symbolic score (*Latticed Window*), as a reentry of musical *lógos* into sonic matter. The technological question, here, is equivalent to the sonic machine.

### Sub-semantic listening vs. musical code

It has been in linguistic research that effective algorithms for recognition have first been developed - as transformation of physically measurable wave forms of speech signals into electric impulses; such operations are based first on electronic transduction and then the transformation of the time-signal to its frequency number.\(^{71}\) Sonicity can not be reduced to the dynamics of waveforms, but encompasses mathematical operations and subsequently their machinic computing as well. Once a series of digits can represent waveforms, sound is liberated from its acoustic phenomenology. The statistic tools from corpus-based linguistics have been adopted for music analysis: "While the basic elements and features (or tokens) over which statistics are computed naturally differ between linguistics and musicology, the statistical concepts that allow us to infer regularities within the specific domain are quite similar or nearly identical. Among the chief statistical concepts that can be derived from frequency counts of tokens / features, and that are employed in both fields, are Markov models, entropy and mutual information, association measures, unsupervised clustering techniques, and supervised classifiers such as decision trees."\(^{72}\)

The agenda of emancipating sound from music is media-epistemological indeed: It has been signal recording technologies and media theories (*avant la lettre*) which heightened awareness of the physicality of sound as vibrational event (both mechanical and electro-magnetic). In terms of ontological unrevealing, it is techno-logical analysis (such as spectrography and Fast Fourier Analysis) as well counts as a better "understanding" of sound than in human hearing itself.

For the media-archaeological understanding, the musical structure does not already unfold in a silent decoding of the score (as claimed by Theodor Adorno), but only as actual enactment, in its operative implementation in structurable matter - be it machine listening, or human cognition.

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\(^{70}\) Richard Beaudoin and Andrew Kania, A Musical Photograph?, in: The Journal of Aesthetics and Art Criticism, 115-127 (121)


Is "musical meaning" dependent on sound as event in matter? In the symbolic order of score notation, "structural listening can take place in the mind through intelligent score-reading, without the physical presence of an external sound source"73, as diagrammatical unfolding of music. As conceived by Theodor W. Adorno, "the silent, imaginative reading of music could render actual playing as superfluous as speaking is made by reading of written material"74.

Musical events (from noise to music) are not perceived by the human ear alone. Technological analysis not only provided the means with which to better understand bodily and neuronal affects; they have a musical understanding themselves.

When sound recording changed from technical signal recording (such as analog phonography) to calculation (in digital computing), this was not just another version of its materialities, but a conceptual change.

"Music" as cultural art form, in Western tradition, does not belong to the sonic realm, since it is primarily conceptual; from there stems its affinity to early programmed computer music such as Lejaren Hiller's Illiac Suite composition. In 1984, IBM Germany edited a combined book (Heinz Josef Herbort) and LP record called Computer-Musik, with the appropriate sub-title "Vertonung im Zeitalter der Prozeßrechner".

Logocentrism becomes (algo)ryhtmic. Vilém Flusser, in Lecture 16 at Sao Paolo, defines music as "any set of sounds purposely composed by the human intellect", while at the same time clearly separating between music as epistemic structure and its physical implementation as audible sound. In the 1980s, Vilém Flusser lectured on the musical code as both concrete and abstract at the same time. Music, like mathematics, is an abstract code, triggering an intellectual process which Flusser termed "pure music"; even "visual codes become spontaneously 'musical'" once they no longer mean the outside world, "but inner, mental processes"; the media artist "transposes the processes of his brain onto [the] apparatus".75 Flusser's enthusiastic correlation of music with mathematics looks at "pure music" as freed from discursive (aesthetic or cultural, even phenomenal or neurobiological) restraints. This situates human "musical meaning" in a non-historicist tempor(e)ality in itself - a truly structural, archaeological concept. Under this perspective, computer music is not simply a creation of the 20th century, but a recursion of the oldest concept of occidental music as such. All of the sudden, łógos becomes musical again - in a deeper sense of epistemé mousiké.

74 Subotnik 1996: 161 f.
75 Flusser, Letter to the editor of Leonardo Magazine in review of an article, 1987 (information by Rodrigo Maltez Novaes, Research Fellow Vilém Flusser Archive, University of the Arts, Berlin)
Leibniz' modelled musical understanding within humans to be "a recondite arithmetical exercise" by the soul "which is unaware that it is counting". Such subliminal calculations actually happen in computations which are fast enough to complete a given task in real-time; time-bound model of musical reasoning. There is "musical meaning" even in the "transition time from straight to curved flight" of aeroplanes, as calculated by the Bell Labs in 1943; its ca. 3 secs corresponds with the human "time-window" of the present. Anti-aircraft artillery literally counts with such anticipatory timing and describes it in musical terms: "There is a silent music to it."77

In anti-aircraft prediction, the pre-calculated lists based on statistics become part of the actual present itself, its register, online as condition of data processing in real-time.78

When discovering sub-semantic poetic respectively musical articulation, interpretation results from measuring. Separating "music" from "noise", Norbert Wiener, with his method of harmonic analysis (borrowed from musical terminology) was interested in responses of a linear resonator to random impulses.

["This is physically realized by the well-known 'shot-effect' in vacuum tube circuits. In such a circuit, the current is carried across the vacuum by individual electrons, and, since these are indivisible, is subject to fluctuations which are independent for non-overlapping intervals of time, and have a constant mean square average."79 An impulse signal - be it an enemy aircraft, or electrons - can then be separated as fluctuating ones.80]

"[M]usical time is the organization or the set of forms 'imprinted' [...] on sonorous matter, on sound."81 Therefore sound is material, and music conceptual. If music is sounding matter shaped in symbolically ordered time, it is drama, while coded writing of music is symbolical time. "Real" time only takes places in analog signal recording or digital signal processing. Philip Glass, in 1974, remarked on Repetitive respectively Minimal Music: "So bleibt zu hoffen, daß man dann in der Lage sein wird, das „Jetzt“ der Musik wahrzunehmen, frei von jeder dramatischen Struktur, als ein reines Medium des Klangs"82 - which subtracts the very term "music" itself.

Only when a musical score is decoded and incorporated into human performers or implemented into signal processing machines, it can be articulated as

76 NA-227-D7-GP. Box 12, Folder Project 11, "Diary of DJS Conference at NACA v. 9. März 1943, here quoted after: Roch 2009: 74
77 Robert Silverberg, as quoted by Claude Shannon; here: Roch 2009: 188
78 Roch 2009: 162
79 Norbert Wiener, On Linear Prediction [1941], 1 (NA-227-D7-GP, Box 4, Folder: Project 6), quoted after: Roch 2009: 57
80 Roch 2009: 58
82 Quoted after program brochure of the performance (Berliner Kammeroper) In the Penal Colony, music: Philip Glass, Hebbel-Theater Berlin, November 2002, 7
sound. "Music" is the semantic content of "organized sound"; the "sonic" message of a vibrational medium is the experience of time, just as in technological operations: "Media mediate change and are therefore the material form of time."

Sound moves inbetween musical meaning in what it attempts to portray, and communication engineering which measures and calculates the effects sound and frequencies have upon humans. "Musical meaning", at first glance, is excluded by communication engineering; Claude Shannon defines artificial languages abstractly, as "a stochastic process which generates a sequence of symbols". Warren Weaver, though, suggested to add the semantic dimension to Shannon's seminal diagram: "One can imagine, as an addition to the diagram, another box labeled 'Semantic Receiver' interposed between the engineering receiver (which changes signals to messages) and the destination. This semantic receiver subjects the message to a second decoding, the demand on this one being that it must match the statistical semantic characteristics of the message to the statistical semantic capacities of the totality of receivers, or of that subset of receivers which constitute the audience one wishes to affect.

"Semantic" listening concentrates on musical objects like a melody. Whereby a melody is basically a contour kept and recognized in memory "over time" (in both senses), the time-critical approach of media archaeology rather concentrates on non-harmonic micro-figurations of temporality within the sonic event. Effective algorithms are capable to identify "musical" qualities such as dynamic time warping, and to extract "the repetitive strucutre of an audio recording".

"Objects of music cognition like melodies, rhythms, and harmonies [...] seem to be mentally represented in a form comparable with symbolic encoding formats."

Computational "Deep Learning" conceptually aims at "musical cognition" previously limited to human brain capacities - a reentry of the archetypal cybernetic hypothesis that "musical" aesthetics in principle (en arché) is re-definable algorithmically, mechanizable as a turingmachine.

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84 Barry Truax, Acoustic Communication, Norwood, N. J. (Ablex) 1984
86 Weaver, in: Shannon / Weaver 1963: 26
87 See Müller 2007: 69
89 Müllensiefen et al., 133
Cognitive processes like memory encoding, retrieval and similarity perception are obviously influenced by the familiarity of the musical material that is to be processed.⁹⁰

Techno-logical understanding differs from of sense-making in human hearing. Claude Shannon, in his notorious diagram of communication engineering, makes a difference between the technical reception and the final "understanding" of a received message. The ear becomes an electronic receiver. Zwicker called the ear a "Nachrichtenempfänger", with the brain being the final destination. Does media-archaeological analysis arrive at its limits when it comes to explaining "musical meaning"? A bridge, though, are the measuring instruments and modeling algorithms (software) for brain research. To what degree is the identification of "musical meaning" itself an effect of such an apparatus?

The research group Music, Mind, Motion, Machines⁹¹ works on music cognition, by application of sensor technologies, motion tracking cameras, and machine learning which is an actualization of the cybernetic premise. Motiongrams and sonograms made from recordings of oral poetry or musical performances allow to identify the correlation of musical meaning and gesture, just like articulated speech in its rhythmic pattern when expressed on a typewriter. Juste as Nicolai Bernstein analyzed piano play by chrono-cyclograms in post-revolutionare Russia⁹², motion capture of musical gestures nowadays includes computer vision techniques, infrared, electromagnetic, ultrasound, mechanical and inertial motion capture systems. Successful synthetic production of semantically "meaningful" music sensations are the proof that "musical meaning" can be reduced to second-order syntax by techno-mathematical analysis.

LISTENING TO SONIC EXPRESSIONS WITH MEDIA-ARCHAEOLOGICAL EARS

Media-archaeological argumentation turns the notion of sound upside down in order to reveal, below its apparent auditory phenomena, its epistemological essence which is an enunciation of specific tempor(e)alities. The notion of "implicit sonicity" reveals the hidden chrono-epistemological implications of sound itself. While sound as acoustic vibration is a physically material event, in its temporal form ("implicit sonicity") which affects the human sense of time it is volatile and immaterial. How does sound as matter relate to its immaterial timing?

In a fundamental sense, sound matters as time-critical articulation. The concept of "sonicity" as epistemological approach is rather related to media-archaeology than to the acoustic. Sonicity happens as non-material oscillations even without being heard as acoustic "sound" any more. "When we see rhythm preserved in a radio aerial, we cannot stop the image of a reciprocal action

⁹⁰ Muellensiefen et al., 136
⁹¹ See Rolf Inge Godøy / Marc Leman (eds.), Musical Gestures Sound, Movement, and Meaning, New York / London 2010 (Routledge);
http://www.uio.no/english/research/groups/fourms
⁹² See Julia Kursell, "Moscow eye" xxx
between the geometric and the temporal from intruding into our thought. It is therefore on our best interests to regard things as truly the products of stationary waves. Periods are spatio-temporal function. They are the temporal face of material things. As it vibrates, a thing reveals both a temporal and a material structure.  

The almost immaterial sonicity of electro-magnetic waves, far beyond simply a phenomenon in acoustic culture, make "sound matters" a fundamental event of being-in-the-world. There is sound in the machines themselves, in symbolic representation (data) and and non-symbolic occurrence (signals).

According to Norbert Wiener's seminal cybernetic definition, information - measured in bits - is "neither energy nor matter". Is the current interest in sound therefore a "post-digital" nostalgia for vibrational matter? Sonic auscultation is an attempt to capture the volatility of sound and reveal its temporal message in a concrete manner through the algorithmic stethoscope, which is software for sound analysis.

Spectral analysis of sound transforms the signal from the time domain into the frequency domain. The analytic science has become aesthetic practice in "spectralism" as compositional technique in contemporary music, where the experimentation of micro-times is being replaced by mathematical patterns.

### Sound art matters: Implicit "sonicity"

In discussing the essence of the tone, G. W. F. Hegel defines it in its temporal essence: "Ein Verschwinden des Daseins, indem es ist" - a disappearance of being, while it exits. The commonality of sound, vibration, light, and technical image lies in their equal condition that by analytic measuring media they can be identified as time-critical frequencies. The existence of sound in and as time signal is twofold: its explicit tempor(е)alities in human perception and its implicit dynamics as epistemic object.

Most media studies have originated either from literary studies, or from theater, film and television studies, with a neglect of the auditory channel of communication. The alliance between sound studies and media archaeology results from a focus on implicit "sonicity", understood as time-based signal processing, as its structural link.

The privileged alliance between technological events and musical sound is based on their common denominator which is its temporal processuality. This is evident in a central electro-technical device: the resonant circuit, otherwise significantly called "tuned" circuit. Such an electric circuit consists of an inductor and a capacitor in mutual connection. "The circuit can act as an

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93 Gaston Bachelard, The Dialectics of Duration [FO 1950], Manchester (Clinamen) 2000, 78
94 See Hugues Dufourt, Musique spectrale: pour une pratique des formes de l'énergie, in: Bicéphale no.3 (1981), 85-89
electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency." Resonant circuits are used either as sender (for generating signals), or as receiver (for picking out a signal at a particular frequency from a band of carrier signals), particularly in radio technology, up to the mobile media in digital wireless communication.

In an experiment from 1889, David Lodge placed two resonant circuits next to each other, each consisting of a Leyden jar connected to an adjustable one-turn coil with a spark gap. When a high voltage from an induction coil was applied to one tuned circuit, creating oscillating currents, electric sparks were excited in the other tuned circuit only when the circuits were adjusted to resonance. Not by coincidence engineers borrowed the terms to describe the micro-temporal event of oscillatory electro-magnetic discharge from musical science. "Lodge and some English scientists preferred the term 'syntony' for this effect, but the term "resonance" eventually stuck" (ibid.).

What McLuhan once daringly termed "acoustic space", is more fundamental than what the human ear can hear, indeed. As the radio producer Tony Schwartz wrote in his book *The responsive chord* in 1974: "In discussing electronically based communication processes, it is very helpful to use auditory terms [...] like feedback ... reverberation ... tuning [...]."

"Sonicity" inbetween vibrational force and electro-magnetic waves

In *The Audible Past*, Jonathan Sterne differentiates sound as perceptual quality from mechanical vibration as physical event: „As a part of a larger physical phenomenon of vibration, sound is a product of the human senses and not a thing in the world apart from humans. Sound is a little piece of the vibrating world“ and „somewhat human-centered“. But some conditions must be given "for something to become recognized, labeled and valorized as audible in the first place".

Vibration encompasses both a „dissolution of matter“ as well as „sensory experiences of things which vibrate“. Vibration (such as in high frequency radio) operates even before being translated into sense-data called sound, light, heat - against „purely audiological conceptions of sound“ which limit the frequency range. Against a „naive physicalism“ and a „phenomenological anthropocentrism“, Steve Goodman defines the "ontology of the vibrational force" as an "in-between of oscillation, the vibration of vibration, the virtuality of the tremble. Vibrations always exceed the actual entities that emit them. Vibrating entities are always entities out of phase with themselves."
The theoretical conceptualization of vibration carries itself a temporal index: In late 18th and 19th century, "new technologies and scientific theories heightened awareness of the physicality of sound as vibration", while at the same time generating non-mechanical vibrations like the electro-magnetic oscillation, technologies of telephony and radio. Tactility is the mode in which sound can be experienced by humans as vibration - different from the electro-magnetic field ("light") which does not mechanically enact pressure.

The English noun "sound", in German, splits into two different notions: a) Schall which is the physical acoustic air pressure which can be perceived by the human ear and hearing; b) Klang which names the periodic, harmonic sonic events.

Taken at face value, sound is "mechanical disturbance from a state of equilibrium that propagates through an elastic material medium". But German language differentiates between Schall, Klang, Ton. In English, the semantics of "sound" embraces all this trinity.

Sound excludes noise by definition - but noise is integral to communication theory. Sound therefore is too limited in its epistemological scope. The notion of "sonicity" includes noise as the stochastic alternative to music in Iannis Xenakis' sense and in terms of electronic music: subtractive sound synthesis creates "order from noise", filtering frequency bands, an all-encompassing "drone" ambience which is continually present throughout and from which sound can be extracted - different from the traditional Occidental additive notion of sound from single harmonic proportions or sine waves. Additive music builds sonic events up synthetically, with its base being silence, whereas the subtractive musical concept actually begins from sound. Here, all the notes and possible notes to be played are present before the musicians even start playing.

Sonicity refers to the specific temporal knowledge which is implicit within sonic instruments of analysis and synthesis on the one hand; in that sense, "sonic revelations" of the vibrational qualities of the human eardrum arose from Hermann von Helmholtz' artefactual resonators. Another kind of insight into sonic temporality arises from graphically or mathematically derived sound. This even extends to the concept of non-struck sound like the theoretical fiction of vibrational forces called "ether".

At that point, the semantic associations of "sonicity" might start to get misleading. In 19th century discussions on the nature of electro-magnetic phenomena, acoustic terms have been borrowed, e.g. Maxwell's notion of the "electrotonic state". It had been Christiaan Huyghens' "undulation theory" which equalled light to acoustic waves, resulting in the literally "media".

104 Trower 2012: 2
105 Trower 2008: 134
106 Encyclopaedia Britannica, 2003
theoretical fiction of an ether. But the equation of electro-magnetic “waves” with elastic mechanical vibrations is just a heuristic model to gain metaphorical evidence (Anschaulichkeit) of an otherwise directly imperceptible event. Maxwell cautions on the (otherwise useful) analogy between light and the vibrations of an elastic medium.

From bodily sound … to the all-embracing sonic?

"Sound matters. It mediates between the real and the virtual, connects the physical reality of acoustics with the mental reality of the muses." But even if the affective potential of sound is clearly a focal point, "yet it constitutes only one aspect of an investigation into the distribution, modulation, and perception of frequencies". Therefore sonicity might be liberated from sound. With the traditional distinctions between noise, sound, and music being increasingly blurred in artistic practice, "the concept of 'the sonic' [...] as an overall category [...] transgresses the limits of the musical and the acoustic" (ibid.) and opens into "the spectrum between bio-acoustical field recordings, brainwave entrainment, binaural beats, biofeedback, psychoacoustics, noise, and sub-bass vibrations" (ibid.). Such vibrations are delicately moved matter.

Material sound versus electro-magnetic sonicity

Even if sound is - to human perception - the most immaterial matter, still it is different from the electro-magnetic waves which touch the human eye as really immaterial "light". Sergei Eisenstein was wrong when the asked "to remove the barriers between sight and sound". In terms of harmonic relationships there might be a symmetry between the visual and the auditive, but in terms of (electro-)physics there is an epistemological asymmetry between mechanical, violent vibrations and electro-magnetic "waves". Optophonic "listening" to the "sound" of visual patterns by sonification rather obscures this fundamental difference.

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109 "Elektrotonischer Zustand", in: James Clerk Maxwell, Ueber physikalische Kraftlinien [Ostwalds Klassiker vol. 69], 5
110 Criticized by Albert Einstein, Äther und Relativitätstheorie, Berlin (Julius Springer) 1920, esp. 9f
111 Josef Maria Eder, Photochemie (die chemischen Wirkungen des Lichts), Hallen (Wilhelm Knapp) 1906, 11
114 CTM 2015 theme
115 Sergei Eisenstein, the Film Sense, New York 1969, 87
(Ultra-)Sonic Imaging

The electronic image, different from traditional painting, with its 650 successive lines every 25th / second, only exists when succeeding within a time-critical window of synchronized presence. Video artist Bill Viola actually listens to "The Sound of One Line Scanning". Marshall McLuhan actually termed electronically mediated communication "acoustic space".

Ultrasound imaging, known from medical diagnosis, itself is images based on sound, where the (comparative to EM waves) slowness of acoustic waves (echo delay) are used to create electronic signals which can computationally be transformed into two-dimensional visual data. Such sound phenomenally is not experienced directly (binaurally) but indirectly seen, as image.

Ultrasound, by definition, transcends (above 20 kHz) the realm of acoustic signals which can at least be recognized within the audible range of the human ear.

Different from visualised "light sound" from celluloid in cinema, in sonography the inaudible sound is visually revealed. The age of sound film is linked to the functional (Fournier d'Albe) or aesthetic (Raoul Hausmann) "optophone".

Visualising sonic similarity

Many algorithms for audio content analysis already bear resemblance to visual retrieval techniques, such the Query by Image Content (QBIC) system. The Audacity software tool allows for sonic frequency analysis via the optical channel itself, by means of waveform display, spectrograms and sonagrams, displaying how the energy distribution changes in the frequency band over time. In sonography, the final graph of the sound event three-dimensionally plots frequency vs. amplitude vs. time. Audio content identification occurs in two ways, one phenomenal (for human perception), and one media archaeological (for machine listening) - from auditive sensation into a visual display, and into numerical computation.

Current audio analysis software predominantly displays visual interfaces, as indicated by the very name of Sonic Visualiser, representing time, frequency and energy of the sonic event. The software package literally allows for the visual comparison of different recordings of the same musical piece and to navigate across a number of such recordings, e. g., "how Rubinstein played Op. 6 No. 1 in his 1939, 1952, and 1966 recordings", while further allows for detailed analysis of performance timing.

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116 In: xxx Lexier (ed.), Sound by Artists, xxx
Audio signals radically (and essentially) unfold on the time axis, against which the visual regime serves to abbreviate temporal extension, with the image as compressed information on sound. Waveform and spectral displays turn knowledge from the attentive ear into the analytic eye. The visual displays of an \( n \)-dimensional search space becomes appropriate for browsing large sound databases where human acoustic memory would fail - while the machine simply calculates. Even what appears just similar to human perception, is exact in techno-mathematical terms. The algorithmic ear, in that respect, is relentless.

**The sonified Wunderkammer**

The electro-sphere, appropriately defined for analog broadcast media as synchronous "acoustic space" by Marshall McLuhan (and currently transformed into asynchronous "rhythmic space" in pulse-modulated digital mobile communication), separates the new Wunderkammer from its visually oriented historic version. All is different when the Wunderkammer objects become sonic and methods of "digital archaeology" as operative image analysis are applied to *sonify* the image-memory, resulting in a continuously evolving composition. This is no deliberate, but an algorithm-based, rule-based, in strictly Foucauldean terms *archival* transformation\(^{119}\), giving a voice to the Wunderkammer, sonifying the artefactual collection.

Beyond the notorious Vocoder (the electronic device for speech synthesis resulting from spectrographic speech analysis for efficient voice transmission), the natural itself can be given a "voice" by un-natural means. In Ryan McGee's, Joshua Dickinson's and George Legrady's multimedia installation *Voice of Sisyphus*, a black & white photographic image from the 1970s displaying a hotel scene "At the Bar" is filtered by a computer program which then reads the segments and produces sounds out of them.\(^{120}\) From a digitally scanned image of a Baroque Wunderkammer as well, several regions and items can be automatically identified and then repositioned over time, therefore allowing for the subsequent sonification of the items. "Unlike the spectrograph approach used by most graphical synthesis programs, such an image-to-sound technique is derived from raster scanning of pixel data. By adding frequency domain filters, polyphony within a single image can be achieved."\(^{121}\) Sound spatialization filters and segmentation algorithms thereby try to "make sense" of a *Wunderkammer* from a signal processing point of view. What human visual perception recognized as shapes and *Gestalt* does not sound melodic when audified: "Non-acoustical data is inherently noisy when audified since it is not a time series of pressure data obeying the wave equation" (McGee et al.).

\(^{119}\)Ryan McGee (image analysis, audio and spatialization software), Joshua Dickinson (assisted with the audio composition software), George Legrady, VOICE OF SISYPHUS: An Image Sonification Multimedia Installation, presented at: The 18th International Conference on Auditory Display (ICAD-2012), June 18–22, 2012, Atlanta, USA

\(^{120}\)See http://vimeo.com/30238729

\(^{121}\)McGee / Dickinson / Legrady 2012, "abstract"
Digital scans of Wunderkammer paintings can be converted into its sonic equivalents as MP3 files, based on defaults of the sonification software Photosounder - which, as a re-entry of the Wunderkammer as its diagrammatic image, can be in return visualized in its wave forms and frequency domain.\textsuperscript{122}

On the y-axis of such a digitized image, each line of pixels, by means of parameter mapping, is related to a defined frequency generated by an oscillator (sine tone generator). Line by line a spectrogram is being produced in which periodicities or non-periodicities can be detected and thereby can be sonified. By sonifying the otherwise spatial configuration of the Wunderkammer, its temporalization unfolds: no more museum, but music. From that results a really (electro-)acoustic Wunderkammer, or a huge archive of sound items from techno-mathematical culture.

\begin{center}
\textbf{Sound & matter \textit{versus} the electronic audio signal}
\end{center}

All kind of "waves" are a form of energy transfer without physical transport. Still there is a radical difference between mechanical and electro-magnetic waves. Acoustic vibrations are among the most immaterial articulations of materiality. Not only can physical matter can be forced to vibrate, but - as pointed out by Henri Bergson - matter itself consists of vibrations, that is: implicit sound.\textsuperscript{123} Matter thus resolves "into numberless vibrations, all linked together in uninterrupted continuity, all bound up with each other, and travelling in every direction like shivers through an immense body"\textsuperscript{124}.

But "sound" relates to "matter" only in the acoustic sense of mechanical vibrations. The oscillations of the electro-magnetic field are a different kind of sound. Let us therefore undo the tight sound/matter coupling, in favor of a more processual, time-critical notion of sound as signal event.

When propagated in a physical medium like air or water, sound is the most ephemeral form of matter; itself it has no solid materiality but is matter unfolding in time. Matter here becomes a temporeality, like an analog electronic image which the video artist Bill Viola once described as "The Sound of one-line Scanning". "Phonovision" was the name given to gramophone records as storage medium of the earliest electro-mechanical Baird-Television picture series.

When mechanically propagated sound is being technically transduced, this is not simply a linear translation, but it changes its essence from acoustic to electric signal. Within a telephone line, or when stored as magnetic charges on tape, a media-epistemological "transubstantiation"\textsuperscript{125} of sound has happened, since as such the audio event becomes accessible to signal processing.

\begin{footnotesize}
\begin{enumerate}
\item \textsuperscript{122} http://photosounder.com, Demo version
\item \textsuperscript{123} As emphasized in the Mauricio Lazzarato, Video Philosophie, Berlin (b-books) 2xxx
\item \textsuperscript{124} Henri Bergson, Matter and Memory, London (George Allen & Unwin) 1950, 276
\item \textsuperscript{125} See Wikipedia: https://en.wikipedia.org/w/index.php?title=Transubstantiation&oldid=696228320; accessed December 21, 2015
\end{enumerate}
\end{footnotesize}
The so-called audio signal, beyond its possible origin in the physical world, may came into existence by electronic generation exclusively - in electro-technical *autopoiesis*.

The real essence of sound such as in Electronic Dance Music or Drum and Base is not primarily bodies but electrons in periodic motion. As (still) human composition or mix or mastering, it is still *musical*, while the *sound* itself has been de-corporalized completely, neither be connected to a human performer or voice nor to a mechanical instrument any longer. What started with the electronic live recording and studio editing, now has become the message of the electronic and algorithmic (that is, techno-logical) medium itself.

Beyond the physical world of mechanical vibrations, the sonic articulation, on the electronic level, exists as signal only. In reverse, electrons - the essential elements of electronic media - are themselves accompanied by waves. Erwin Schrödinger intuitively recalled the oscillating monochord and thereby defined implicit sonicity: "Suppose the electron in the hydrogen atom is analogous to a string - tied at both ends - in a musical instrument. Such a string emits a very definite tone together with its overtones, but not the wavelengths in between. With this idea in mind, Schrödinger [...] set up a wave equation for the electron"[126] - which is the only true "radio", as radiation.

**The electro-acoustic "lab": Cologne versus Paris**

Memory manipulation on and by tape has been common practice in the heroic age of magnetophone-based audio engineering. This actually reminds of the different techno-aesthetics of the Paris electronic music studio run by Pierre Schaeffer with its conceptual *musique concrète*. Stockhausen criticized the Paris studio for its aleatory concept of "found sound" (passive magnetophone recording and then active manipulation) rather than generating electronic sound genuinely from non-environmental electronics.[127]

Only in electronics, the almost pure sine wave as elementary unit exists (which fascinated young Stockhausen). In its physically impossible form, the *ideal* sine wave has a technological existence indeed: within the digital computer as mathematical function expressed in executable code.

A primary difference between the Paris studio of *musique concrète* (Pierre Schaeffer) and the Cologne WDR radio of Electronic Music (created by Herbert von Einem) is not simply an aesthetic but a media-epistemological one: Recording and manipulation of originally physical sound *versus* electronic sound generated by tone oscillators from the beginning, in pure sonicity. There is electro-mechanical kinetics and tactility on the one side, and circuitry-operative electronics on the other.

[127] Tilman Baumgärtel, Schleifen. Geschichte und Ästhetik des Loops, Berlin (Kulturverlag Kadmos) 2015, 100
In artistic practice the active co-agency of the magnetophone has been recognized by pianist Glenn Gould.\textsuperscript{128} Many of such compositions enhance the live performance by human musicians in communication with pre-recorded sound. It has been against this tape-based sampling that, in contrast, the computational paradigm of real-time human-machine-interface developed, such as Roland Pfrengle's piece \textit{Klavermusik} (1984).

Very experimentally, Karlheinz Stockhausen in the Cologne Westdeutscher Rundfunk radio station "Studio für elektronische Musik" generated sine waves genuinely from within electronic oscillators. Notably his piece \textit{Kontakte} (created contemporary to KLT, 1958-1960), in its first version, is not primarily about communicational "contacts" between human instrumentalists and sound machines any more but about the coupling inbetween electronics in its radically non-discursive \textit{autopoiesis}. While for instrumental parts there is a conventional score, the electronic parts are in graphic representation.

[While sound film recording of musical articulation remains external to the instrument-player (machine-body) system, the photo-electric generation of sound from light waves from within an instrument (such as the Welte organ) is truly media music.\textsuperscript{129}]

\textbf{De-materialization? Digitalized "sound"}

When acoustic sound becomes transduced into an electric signal, it can thereby modulate a radio high frequency carrier band. Electro-magnetic waves do no mechanically touch the human ear. All the sound is there but unhearable - the implicit sonicity of electromagnetic vibrations, close to what humans perceive as light (especially in Ultra Short Wave radio transmission). The electro-magnetic event is not material any more but an epistemological challenge to re-think sound-as-matter. It can only be phenomenologically observed by its effects or needs mathematically to be diagrammaticized (Maxwell's equations).

Once the analog audio signal becomes digitized, the term "signal processing" becomes fully justified in terms of computing. Coded in binary values, the signal within computing devices shall not be called "audio" any more, even if it can - by digital-to-analog conversion - be emitted via loud-speaker for human ears as sound again. What phenomenologically appears like sound has inbetween (in the techno-logical media channel) gone through a complete substantiation. In digital media, we have lost "sound".

The gap between the material recording of a sonic event and informational ephemerality principally started with the first coded inscription already: the alphabet. The binary code is the smallest possible of such alphabets, and its advantage stems from its distinctive signal-to-noise ratio in signal transmission

\textsuperscript{128} See the "Glossary" explaining practices of audio tape recording and cutting, in: Glenn Gould, \textit{Vom Konzertsaal zum Tonstudio}, Munich / Mainz 1992, 173

\textsuperscript{129} On the opto-acoustic ("optophonic") discs in Welte organs, see Peter Donhauser, \textit{Elektrische Klangmaschinen}, Vienna - Cologne - Weimar (Böhlau) 2007
and signal storage, such as Pierce and Shannon defined a "Philosophy of PCM".\footnote{In: xxx}

Friedrich Kittler, in his writings on the entanglement of music & mathematics, reminds that one and the same alphabet has been used to notate verbal language, music and mathematics - a "unicode" which unexpectedly returned as alphanumeric notation with the digital computer. This recursion can not be described in terms of cultural history any more but calls for a different diagram of cultural timing.

Digitized signals at first sight resemble the tradition of music notation (the score), but in addition, they are endowed with operational activity: they are algorithmically executable. Symbolic archival permanence is almost time-invariant, sublated from change with time, leading to a-historical immediacy in the moment of re-play. We are not tuning into the past any more in sonic temporality.

**MEDIA TEMPORALITIES AND THEIR SONIC UNDERSTANDING**

**Media Musicality: The Echo of the "Now"**

E. R. Clay termed the "specious present" in 1882 for a recent past which is delusively given as perception of the now, different from the obvious past. Every electronic image is already the "halo" of an image (William James), "the dying echo of whence it came to us [and] the dawning sense of whither it is to lead"; such an image (like sound) is always already in transition.\footnote{As quoted in: Bill Viola. Installations and Videotapes, ed. Barbara London, New York (The Museum of Modern Art) 1987, 79} New media phenomenology, by combining recent research in neuro science on brain temporalities\footnote{On the neuro-processual time frame ("window of simultaneity") which counts as the human experience of "presence" see Francisco Varela, The Specious Present. A Neurophenomenology of Time Consciousness, in: Jean Petitot / Francisco J. Varela / Bernard Pachoud / Jean-Michel Roy (eds.), Naturalizing Phenomenology. Issues in Contemporary Phenomenology and Cognitive Science, Stanford, Cal. (Stanford UP) 1999, esp. 272f and 276f} with the Husserlean definition of temporal experience (pro- and retention), couples technologies with the human experience of affective temporalities.\footnote{See esp. Hansen 2004, chap. 7 "Body Times", 235-268} Already Marshall McLuhan's notorious theorem of the "acoustic space" opened the notion of electrified media. In media art like Bill Viola's works the "cinema-digital-video hybrid technique exposes the viewer to minute shifts in affective tonality well beyond what is visible to natural perception"\footnote{As paraphrased by Tim Lenoir, "Foreword" to Hansen 2004, xxvi}. If tonality is taken literally, there is implicit "sound" in electronic media, with the sonic not taken in its physical (acoustic, audible) but in its epistemological sense: being an expression of tempor(e)alities. Technological experimenting with media time (and its cognitive experience) lead to sonicity as epistemic media object in the dynamic chronosphere. The privileged relation between sound and technological media is grounded in their analogous time-basedness.
and chrono-poietical time-basing. New media articulate themselves in symbolically ordered time, which is their media-dramatic musicality.

**On sonicity: Sound as epistemic object of (media) analysis**

In assuming the epistemological dimension of sonic memorization, the analysis goes far beyond to simply doing justice to *auditory memory* which indeed "has been largely neglected in memory studies in favour of visually-oriented arts of memorization [with their long tradition within rhetoric (ars memorativa)]".

Electronic tuning allows to change a piano's tuning (its "temperament") with ease from universal "equal temperament" to time-specific ratios. "Modern pianos are tuned in "equal temperament," which divides each octave into twelve equal half-steps. The frequency of a note is adjusted up or down, sacrificing some harmony in all keys so none are too dissonant. On the other hand, in many tunings that were popular in the Baroque period, intervals are extremely pure in some keys at the expense of others, increasing the dissonance in those keys. Variable temperaments are essential tune into the earlier *Stimmung* of musical action. Techno-mathematical re-turing of instruments (even in microtones) serves thereby as true media archaeology of the sonic past.

"Sing me, Muse, the deeds of a man called Odysseus", Homer's epic starts. What if the Muse is not only reduced to the narratives of "oral poetry" to be registered and displaced in writing symbols which replace (and "technologize" the oral signal with all its rich overtones (tuning, pitch, timbre, rhythm), but phonographically remembered essentially sonic in itself?

Erkki Kurenniemi is "an unsung" pioneer of electronic art, the back cover (endorsement) of the DVD *The Dawn of Dimi* articulates, quoting *The Wire* (January 2003): "Viewed from a historical perspective, Kurenniemi's music foretold digital directions in rhythm, noise and jumpcut editing, only back then no-one was listening." Is there a "historically" delayed listening? Yes and no: not historically (since this cognitive sphere is a function of historiography and

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136 As defined in the call for papers to the workshop *Auditory Memory and Sound Archives from the Late-Nineteenth Century to the Present*, University of Amsterdam, 18 February 2013


138 In the sense of Walter Ong, *Orality and Literacy. The Technologizing of the Word*, London (Methuen) 1982

139 Published by Kinotar Oy and Museum of Contemporary Art Kiasma, Helsinki 2003; editor: Mika Taanila
the alphabetically recorded and organized archive), and yes: temporally
delayed, reminding of the physically given evidence that every "presence" of
aural listening already involves the delayed transfer of acoustic vibrations
through air with a speed of around 330 meters/sec. - medium time in terms of
Aristotle's "acoustic" definition of physical media.

Sonic eventality is not only time-based, but in a more radical reading it leads
humans to experience time at all. The neo-logism of "sonicity" aims at catching
"sound" as an epistemological object of knowledge from a media-philosophical
perspective. The audible section of the bandwidth of sonicity (acoustic sound) is
just the deceptive top of the ice berg above the water level, or comparable (in
less "layer" metaphors) to the visible part of the electromagnetic spectrum
which animals perceive as "light". Das Sonische, a neo-logism in German
language (different from Klang which is acoustic "sound") in this context refers
to the inaudible vibrations ("analogue") and rhythms ("digital") within the
electronic field (Sonik).

Sound as epistemological form of timing refers to continuous ("analog")
vibrational and discrete ("digital") frequential dynamics of all kinds, ranging
from the most precise (electro-)physical micro-moment over the human affect
of temporal perfection up to repercussions of what traditionally (fixed by
writing) used to be called history. But to understand the ways that media
inscribe themselves on our bodies, we need a philosophy of time that recognizes
the production of a different time-writing. "Before the phonograph, no sound
had the option but the be fugitive. A historical rupture in the nature of sound
arises that, in turn, rewrites its entire history." But maybe this irritation is
more fundamental: not just a historical rupture, but a rupture of the privileged
dominance of historical discourse over the phenomenology of emphatic time as
such. The generation of vocal or otherwise sonic "presence" of cognitively
known absence induced by the phonograph does not simply ask for a re-writing
of media historiography, but requires different ways of writing temporal
figurations as such - a kind of archaeography which the oscilloscope making
visible sonic wave forms performs for long time already.

Sound allows for the co-experience of transient time and even time-invariant
affects. It is this processual experience which the sonosphere shares with high-
electronic media. Just like culture tries to save sound itself from its ephemeral
 temporality, signal recording media for the first time in cultural history
mastered the time axis towards arbitrary manipulation.

The term "sonicity" does not refer to the apparent phenomenological quality of
sound but rather to its essential temporal nature which is its subliminal
message behind the apparent "musical" content.

Nicole Oresme's late medieval Tractatus de configurationibus qualitatum et
motuum defines the "sonus" in its physical materiality as a function of the time

140 Peters 2004: 193
141 This argument refers both to Marshall McLuhan's central argument ("the
medium is the message") in Understanding Media (1964, chap. 1) and to Martin
Heidegger's epistemology of technology's essence, in: The Question
Concerning Technology and other Essays, New York (Harper and Row) 1977
axis\textsuperscript{142} and thus comes close to the present definition of sonicity as epistemic articulation. The diffuse genealogy of the term \textit{sonus} ranges from the concrete physical materiality of sound up to its epistemological definition\textsuperscript{143} for which the neologism \textit{sonicity} might be allowed. Sonicity refers to knowledge about implicit periodically varying functions of time.\textsuperscript{144}

Acoustic sound - in order to be communicated beyond its natural physical limits - must be technically transduced in order to fit to a technical channel such as the telephone line or electro-magnetic radio waves. While passing as transduced signal (voltage-controlled current), sound is in its implicit state.

Volatile sound and speech must be converted implicit in order to pass the channel of cultural time and historical tradition: it must either be signal-recorded in phonography or symbolically coded by musical notation.\textsuperscript{145}

According to Marshall McLuhan, telephone, gramophone, and analogue radio were technologies of post-literate "acoustic space" which he declared on the climax of analogue electronic broadcast media culture. "Sonic" space is understood here as the epistemological existence of sound, somewhat opposite to the term in physics.

The term "sonic epistemologies" itself is awry; ancient Greek \textit{epistemé} is already triggered by the visual bias of alphabetic writing (as defined by McLuhan 1962). \textit{Sonic Epistemologies}\textsuperscript{146} is sometimes called "acoustemic" already.

Marshall McLuhan made a crucial discovery about the intrinsically "acoustic" structure of electronic mediascapes. The immediacy of electricity is valued essential as the definite difference to the Gutenberg world of scriptural and printed storage of information: "Visual man is the most extreme case of abstractionism because has has separated his visual faculty from the other senses [...]. [...] today it is threatened, not by any single factors such as television or radio, but by the electric speed of information movement in general. Electric speed is approximately the speed of light, and this constitutes an information environment that has basically an acoustic structure."\textsuperscript{147} Very media-archaeologically, McLuhan's terms "basic" and "acoustic structure"

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\textsuperscript{142} "[... aliam vero extensionem habet [sonus, et] motus, a tempore, que nunc vocetur longitudo ipsius soni": Nicole Oresme and the Medieval Geometry of Qualities and Motions, ed. by Marshall Clagett, Madison, Milwaukee / London (Univ. of Wisconsin Press) 1968, Book II, chap. 15 \textit{De natura et difformitate sonorum}, 306

\textsuperscript{143} See Frank Hentschel, entry "Sonus", www.sim.spk-berlin.de/static/hmt/HMT_SIM_Sonus.pdf (accessed July 2013)


\textsuperscript{145} Peters 2004: 188

\textsuperscript{146} No. 4 (special issue) of the Journal for Sound Studies (JSS), xxx

\end{flushleft}
evidently refer to an epistemological ground, not to the acoustic figure in its phenomenological body-related sense.

In an epistemological sense, the sonic is not about (or limited to) the audible at all, but a mode of revealing modalities of temporal processuality, up to the "superstring" theory of today. Already Henri Bergson formulated his dynamic idea of matter in the sense of vibrating waves and frequencies.\textsuperscript{148}

"The message or effect of electric information is acoustic" (McLuhan) - even when it is perceived as an electronic "image" - as defined by the video artist Bill Viola in his essay "The Sound of One Line Scanning"\textsuperscript{149}.

McLuhan's "acoustic space" is oscillating time and implicitly re-turns in Gilles Deleuze's "interval" philosophy. But information in "online" worlds come a-simultaneous from topological directions which recalls a different structure of the act of hearing. "Sonic" tempor(e)alities unfold on the level of packet switching in the "social net": "Temporalities of flows, bursts, and various techniques and technologies of time management [...] is what characterises the specificity of reproducing existing worlds in network culture."\textsuperscript{150}

Listen to how "prosodic" communication in the World Wide Web sounds like on its basic media-archaeological level, its signal clocking in terms of dactyls: All of the sudden, one of the oldest figures of prosody in occidental poetic speech returns as implicit sound of digital tele-communication - true technopoiesis.

**Sonic tempor(e)alities**

In fact, the sonic ground of the electronic image is "hidden" in the media-archaeological and Heideggerean (\textit{aletheia}) sense: "It is acoustic. It resonates. But this is a hidden ground, because superficially people think they're looking at a visual program. And they're not. They're not looking at all - they're absorbed, involved in a resonating experience."\textsuperscript{151} So-called immersion is rather into a sonic than visual sphere.

There are two kinds of carrying sound through time: "musical" memory as symbolically notated in scores (the archive) and sonic memory preserved in signal-based recording media (starting with the Edison phonograph) which are endowed with "temporal indexicality" (Thomas Y. Levin). Media temporality

\textsuperscript{148} Henri Bergson, Matière et Mémoire [Paris 1898]; in English: Matter and Memory, xxx, 276
\textsuperscript{149} Bill Viola, The Sound of One Line Scanning, in: Dan Lander / Micah Lexier (Hg.), Sound by Artists, Toronto / Banff (Art Metropole & Walter Phillips Gallery), 1990, 39-54
refers both to the symbolical ("digital") and the physically real ("analogue") regime - like the clocking of computers and the "Time-To-Live" which in the Internet for data packets decides about the success of communication in virtual, that is: calculated space.

In the media culture which is experienced as the present an implosion of the despotic parameter "time" into a multiplicity of times and timings in the sense of chrono-poetics occurs. This time machine (not in the sense of time-travelling, but of time-generating mechanisms) is sonic by nature. The term "sonic" here refers to the two bodies of dynamic tempor(е)alities: the waveform and the digital, that is: mathematically intelligent (algorithmic) manipulation of numerically addressable frequencies.

A "musical" composition (or other code), when effectively, that is: physically, implemented in operative media, is in itself a priori already a sonic Versinnlichung as temporal affect. In a more advanced interpretation, sound is even a sonification of time in the strict sense of Latin fictio, since it generates temporality.

Different from functional sonification as defined by Gregory Kramer as "the use of nonspeech audio to convey information" and, more specifically, "the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation"¹⁵², sonicity is about implicit acoustics - which is the "acoustic" in McLuhan's implicit audio sense - a processual mode taken as epistemological term.

The present experimental popular music or avantgarde compositions is characterized by an aesthetic multiplicity which extends the limits of human perception to infra- and ultra sound and to micro-temporal events. This pushing of sonic limits is itself a effect of the almost infinitive flexibility of digital technologies. Thus it makes sense to extend the term "sonic" to non-acoustic time-based eventalities: vibrations and their mathematical reversal which is frequencies.

The (h)ear(ing apparatus) is much more sensitive to micro-temporal (time-critical) processes than the eye. While the flickering of an electric bulb (50 times/sec.) can not be noticed by the after-image in the eye any more (the cinematographical effect), the rising of acoustic pitch from 50 to 100 oscillations/sec. is very well perceived indeed.

This hits a deep epistemological dimension. If the experience of being is not a static one (ontologic), but rather processual (being-in-time), then the definition of existence as "being tuned" ("Durchstimmung" with Heidegger) recalls sonic resonance. "Stimmung", in German, relates both to the voice ("Stimme") and to the tuning ("stimmen") of an instrument, and more sublimely, radio reception - constituting "sonic" media temporality.

"In order for one person to understand what another person says, he must be

'in tune' with him. [...] such intrapersonal synchrony is far more fine-grained than that of any *corps de ballet*. Communication, here, is not simply "a function of social context"¹⁵⁴, but of time-critical signal engineering.

In many respects sound – heard, recorded or transmitted – is radically ahistorical; its specificity could not be captured and subsumed by the logocentrism of traditional narrative historiography. Serious engagement with "the sonic" – sound as sound and sound as time – provides access to a plurality of non-narrative temporalities.

**CHRONOPOETICS AS "SONO-POETICS". The Appeal of Sound as Time-Object and Time-Subject for Technology-Oriented Media Theory**

**So what is "chronopoetics"?**

Chronopoetics investigates the ways technological media are time objects and time subjects; for that reason, the analysis stays close to the actual signals. In order to perform such analysis, it first needs a cognitive training: to get distance from the discourse of cultural history. Historical discourse is all too hegemonic when it comes to discuss multiple temporalities. The media-archaeological cold gaze and listening (both technical and as human understanding) is a way to get - at least momentarily - suspended from that supremacy of historical discourse.

Media archaeology describes technological events on the level which is phenomenologically hidden to human perception. Here, a micro-drama unfolds, both *in* time and in the form of its diagramatic mathematical expression: the frequency domain. It is only by measuring, diagramatic and calculating media that this world becomes accessible to human knowledge.

*Chronopoetics* refers 1. to the "hidden" temporalities *with* in technology, 2. to the phenomenological irritation of human sense of time when being coupled to media timing, and 3. to the philosophical dimension: the revelation of how technical media are position in culturally "deep time".

After getting used to non-historistic ways of rethinking media time, more constructively it takes an active step to develop a new language for the analysis and implementation of such temporalities. While conventional historiography of technology writes "about" media time (that is, in the intransitive mode), a transitive approach to express multiple media temporalities needs to be developed. Next to non-linear verbal forms of argumentation, that results in graphical diagrams and even sonic

¹⁵⁴ Lomax 2005: 277 f.
rhythmograms - and in different temporal moods of looking and listening to media-induced events.

**Rhythmograms and their media-archaeological *Kehrwert***

The theory of music has been the traditional cultural domain to reflect upon different modes of time-based articulation, and has provided a rich terminology for expressing sonic eventality. It is not accidental that in electronics, engineers frequently borrow musical terminology to name time-critical processes - like "resonance" (and the "resonant circuit" as its hardware condition in technical communication between a radio sender and a radio reception. This allows for a word-play, a slight shift of signifier: from technical *chronopoetics* to *sono-poetics*. "Sound" is the bridge between technical media and "music" as cultural aesthetics.

The both effective and affective "message" of sound as physical event is not "music" (which is rather its semantic "content") but its temporal form. Therefore the focus of an epistemological inquiry into sound is on its temporal *gestalt*. The "hidden" tempor(e)alities within technology might be coined as "sonicity". This refers to the implicit temporality in electronic media. In mid 19th century, James Clerk Maxwell explicitly chose a mechanic analogy between electro-magnetic field lines and hydrodynamic oscillations and coined this the "electrotonic state".

Sonic signals in terms of mechanics are vibrational physical events with harmonious partial "tones" - literally ancient Greek *tonos*, "tensions". They have a privileged affinity to the epistemological concept of the "analogue". When, e.g., an archaic computer game is emulated in a current computer but was once created for continuous vector graphics on a cathode rays screen, and if the interface on the hardware level has to be a real vector monitor (which cannot be convincingly emulated by a matrix screen with its aliasing pixels), the amplifiers of the present computer soundcard are being "misused" in order to generate, on the x and y axis, such kind of vector graphics.

Media Studies at Humboldt University once organized a symposium called *Think Analogue!* juxtaposing the "dead medium" of analogue computing with the electronic modular synthesizer in electro-acoustics - which in fact are twin machines. Among others, media artist Benjamin Heidersberger (co-creator of *Van Gogh TV*, an early experiment in interactive television presented at Ars Electronica in Linz and Documenta in Kassel in early 1990s) projected his electronic Lissajous figures created from an oscilloscope. This is an escalation of what his father - a prominent black & white photographer in post-war West Germany - had photo-mechanically created and called "rhythmograms".

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In order to capture the message of Heidersberger's medium, it takes a technology which itself is able to record movement; Ali Altschaffel has cinematographically documented the "Rhythmograph", a mechanical analog computer resulting in visual patterns of photogenic drawings, of Heinrich Heidersberger.\(^{158}\)

There is a remarkable, epistemologically challenging equivalence between a mechanical generation of Lissajous figures, and its electronic expression. Though completely different physical systems, their temporal unfolding is principally (\textit{en arché}) the same. Only in mathematical terms this relation between two incompatible worlds (materiality of mechanical devices vs. immateriality of electro-magnetic waves) can be expressed; therefore the real level of epistemological insight is mathematical. The technical medium to perform this is not the digital but the analog computer.

The hypothesis of analog computing is that an electric voltage circuitry can emulate a mechanical process since in mathematical description (as common denominator) it behaves the same.

What one could actually hear in the studio with Heidersberger's rhythm-poetic machine was not the harmonic oscillations themselves which result from the photographic registering of the light trace produced by the machine movement, but the noise of the machine itself. The visual rhythm emerges by opto-chemical recording: the subject-less long-time exposure of black & white photography. The visual "Rhythmograms" result from the inherent mathematical musicality of a mechanical analog device; Heinreich Heidersberger has built "an analogue computer designed for the combinatorial exploration of mathematical phenomena"\(^{159}\). The truly media-archaeological equivalent to Heidersberger's visual rhythmograms are algebraic formulas: differential equations. Only such radical mathematization resists the metaphysical, esoteric or aesthetic seductions induced by such visual wave forms such as \textit{Kymatik} (Jenny).

Heidersberger's "rhythmograms" continue what in 19th century had started with Lissajous' tuning fork-based figures and later resulted in Heribert W. Franke's electronic "real time" oscillograms. When in 2014 a selection of Heidersberger's Rhythmograms were re-exhibited\(^{160}\), the subtitle was appropriately \textit{das gestimmte bild} - the "tuned" image. There is implicit sonicity in such "technical" images. This ontologically recalls Martin Heidegger's philosophical notion of being as "Stimmung", and in terms of media arts has been expressed by video artist Bill Viola in an early essay defining the electronic image as "The Sound of One-Line Scanning"\(^{161}\). Heidersberger's

\(^{158}\) See https://vimeo.com/89780677. Heinrich Heidersberger himself appears in a 1959 West German \textit{Wochenschau} newsreel with the second version of the machine; see http://www.filmotheke.bundesarchiv.de/video/589598, min. 7:00 to 7:30

\(^{159}\) Andrew Witt, Heinrich Heidersberger. Light Harmonies, Ostfildern (Hatje Cantz) 2014, 11

\(^{160}\) \textit{heidersberger: rhythmogramme}, at Petra Rietz Gallery, Berlin

\(^{161}\) In: xxx
rhythmograms are spatial geometrizations of time-continuous oscillations, thereby freezing the sequential into simultaneity.

Marshall McLuhan, the founding father of technological media studies as academic discourse, frequently referred to so-called "acoustic space". This term does not address the explicit audible sound but rather the implicit "sonicity" of technical articulation - the rhythmic structure and temporality of signal processing and algorithmic operations. In cultural time, technology rather unfolds in "resonant intervals" than in straightforward evolution, as expressed by McLuhan in The Global Village and his Laws of Media. Any algorithm written down as source code has to become implicitly "sonic", that is: electronically implemented as sequential time events, in order not to remain simply an abstract symbolism but effectively computational. This requires temporal understanding.

Contrary to Heidersberger's Rhythmograms (produced between 1953 and 1965) Indeed, today's techno-acoustics is rather beat than oscillations, impulses rather than continuous sound, stochastic noise rather than harmonics.

One way to de-metaphorize sound art is its spectral analysis - the analysis of such temporal tones as tabular mathematics. This causes vibration [...] to assume a numerical existence, a return to alphabet-based epistemology - a recursion of the ancient linkage between number and "music".\textsuperscript{162}

An academic turn to "sound studies" is currently taking place. But is the focus on "sound" justified for a critical approach to digital media culture? The heart-beat of computing (generating its "clocking") is the crystal oscillator with its piezo-electric effect. No sinuidal oscillations but sharp saw-teeth impulses.

In Homer's epic Odyssey, female sirens have been singing, but mechanical sirens (as invented by Cagniard de la Tour) express air pulses rather than continuous waves, discrete signals rather than tones. Only by addressing the sonic time signal in its mathematical form (counting by frequencies), sound can be "heard" by the digital computer. Computational clock time, by clever programming of its data cycling units, becomes truly algo-rhythmic.

**Ubiquitous oscillations (Ørsted)**

The human ear is especially sensitive to micro-temporal changes of pattern and rhythm. Time-critical signal archaeology is not simply concerned with so-called "time-based arts" (which start with oral prosody and theatre already, leading to film and other mass media dramaturgies) but with kairotic, that is: time-critical media technologies.

\textsuperscript{162} For the difference between Heinrich Heidersberger's harmonic Rhythmograms and early computational drawings, see Frieder Nake's Achsenparalleler Polygonzug (1965), in: Justin Hoffmann / Kunstverein Wolfsburg (ed.), Der Traum von der Zeichenmaschine. Heinrich Heidersbergers Rhythmogramme und die Computergrafik ihrer Zeit, Wolfsburg 2006, 24
1803 Ritter writes to Hans Christian Ørsted: "Aller Sinnesempfindung liegt Oscillation zum Grunde. [...] überall, wo nur etwas geschieht, geschieht es auch nothwendig oscillatorisch."\textsuperscript{163} Answers Ørsted: "If we imagine a taut string making its slowest vibrations, we are able to distinguish each vibration with our eyes. Let the speed increase, and now we can no longer distinguish one vibration from the other; we see only the entire space through which the string vibrates filled by it. There is a gap between the point where the visibility of the individual vibrations ceases to the point where the deepest tone begins. Now imagine the vibrations proceeding with increasing speed and producing higher and higher tones; in the end the speed of the vibrations becomes too great to be perceived by the ear."\textsuperscript{164}

Ørsted further, in 1808: "The vibrations continue to increase, and after an interval like the one between the fastest individuality visible vibration and the lowest tone, the vibrations here will rise to the production of the deepest color. It appears in front of the eye as a faint blue twilight, and with increasing vibrations it clears to higher and higher colors and thus runs through all prismatic colors until they have reached the most vivid red. According to this conception, one sense would become an octave of the other on the grand scale of sensations, and all would be subject to the same laws. Thus all sensations spring from the same original force."\textsuperscript{165}

**Geometrization of sono-temporal patterns**

The central sonic event is the sine wave which in its pure form only exists from technical signal generators like tuning forks or electronic circuits, not in nature - just like sculpture in ancient Greek art idealized the actual human body. Instead of writing it on a time axis in its continuous wave form, the sine wave can be alternatively computationally. According to Poincaré, one can divide mathematicians into two types - those with visual and those with auditory intuition.\textsuperscript{166} It is the operativity, the inner sonicity of computing which reveals temporal patterns indeed; that is processual media-archaeology. The algorithmic rhythm of digital calculation can be visualized by rectangular versions of the so-called Ulam spiral. In fact, this is no sound-"image" but a time-diagram.

Similarly, the Moiré effect originates from the "pixelized" image by the grid in half-"tone" photo printing (raster). For color raster printing several grids have to be overlaid, resulting in moirés which correspond to "Schwebung" in sonic impulse series. The moiré projector, overlaying one stable grid (slide) with a

\textsuperscript{163} Quoted here after Siegert 2003: 300
\textsuperscript{165} Ørsted 1808 / 1998: 280
movable second grid (slide), is a sonic composition and device. ¹⁶⁷ A temporal sequence is here translated into a spatial order. ¹⁶⁸

The Ulam Spiral is a method devised by the mathematician Stanislaw Ulam in 1963 for the graphic representation of prime numbers by means of locations on a rectangular spiral.¹⁶⁹ Nikita Braguinski experimented with such data visualization for his Ph.D. thesis on the oblique sounds originating pseudo-randomly from electronic toys and early computer games.¹⁷⁰ The rectangular Ulam spiral representation allows for the visualization of the calculations by the digital computer PASCAL from the early 1960s for prime number calculation - which is all about the hypothesis that it might be possible to detect repetitive patterns in an apparent random sequence.

["Am Anfang der Suche, das heißt im Zentrum des Bildes, sind keine Muster erkennbar. Wenig später beginnen sich auffällige Bänder von wellenartigen Mustern zu bilden, die jedoch zeitweise von Rauschanteilen unterbrochen werden."]

The algorithmic procedure in the PASCAL computer in its time could still be sonified by loudspeakers, since the cycling units of calculation were within the low frequency range of the human ear.¹⁷¹

Before the introduction of the electronic tube which allowed for calculating with ultra-sonic speed almost devoid of material inertia, electro-mechanic computing was audible in itself, like the 4 Hz clocking of the early Zuse 1 computer.

The misuse of electronic radio vacuum tubes as digital switch resulted in a quantum leap of speed in computing; therefore the first fully electronic digital computer, the otherwise silent ENIAC at Princeton, requires explicit sonification to make it understandable for human ears again.


In the early days of digital computing, technological devices for short-time data storage like the acoustic mercury delay line used the slowness of sound waves itself as dynamic storage medium.

So far, the Ulam spiral has been used for the visual demonstration of mathematical regularities. Braguinski proposes the application of the Ulam spiral for signal analysis as well, as an alternative to the usual tools for sound visualization like wave form and spectrogram, with a focus on the identification of structural regularities or deviations on the micro level.

Looking at such geometric pictures, one may have learned to decipher the implicit sonicity in it. The mathematic construction of a rectangular spiral is step-wise created from discrete elements in succession. Such discrete elements may be the sampling values of any digitized signal, thereby translating (rather than simply transforming) the time-domain into the frequency domain which is visual patterns.

This allows to recognize repetitive patterns in the data output of what is called a random generator; immediately it becomes literally "evident" that what sounds like accidental noise, when being produced by a digital device, can only be pseudo-random.

Spatializations of the time axis for the sake of analysis result in a geometrization. Does this deprive the sonic event of its essential message which is time? Is this a re-Pythagorizing of the signal event into a mathematical, "musical" ratio instead of its processual wave event?\textsuperscript{172} This is not simply a technological question but a momentum with epistemological dimension. The time function of a sound signal $s(t)$ can only be approximated by the signals of the sample-and-hold operation in analog-to-digital conversion.\textsuperscript{173}

Fourier transformation allows for translating the physical "time" signal into the frequency domain which can thereby be numerically addressed and mathematically processed - still being the same signal, having lost all its temporality. Fourier analysis supposes that the analyzed signal is \textit{ideally} periodic, reaching back indefinitely into the past and extending likewise into the future. But once again: The pure sine tone does not exist in physical reality. Any physical real signal is time-varying, always being characterized by a beginning and an anticipative sense of ending. Analysis can only focus on the time domain or the frequency domain (that is why Denis Gabor developed his time-windowing of sound analysis in terms of "acoustic quanta").

\textsuperscript{172} See Hermann Gottschewski, Graphic Analysis of Recorded Interpretation, in: Computing in Musicology vol. 8, 1992, 93-96
\textsuperscript{173} See Fig. 4-4 in: xxx Görne, Tontechnik, 2nd ed. 2008, 130
always marked by the trace of its beginning: the *transience* of the signal. There is an existential temporality ("being-to-death") of any physical sonic event in Hegel's and Heidegger's sense. Wavelet-Analysis tries to capture exactly such temporality by slicing the sound.

Not only the composition of sound is analyzed, but its very unfolding in time is visualized.\(^174\)

**Materiality in being: Temporal sonicity of the monochord**

Different from the material artefacts of classical archaeology which are preserved in museums, technical media from past times are not simply monuments which survived into the present, but they are essentially "time objects" ("Zeitobjekte") themselves; Husserl's term refers to objects which are not only a "unit in time", but "contains in itself temporal extension"\(^175\). The technochronological object, in the active sense, is not simply subject to historical time, but an active agency in the media-theatre of time. Given the definition that technical objects become media only in the moment they actually process signals, that is: being in operation, then technological artefacts from the past can not be reduced to their materiality but have to be processual. Then they are timing themselves, undoing historical distance, being radically unhistorical. "[T]he vexing relationship between media, time and history can be viewed as variations on one German verb: zeitigen. It derives from *Zeit* ('time') and is normally a transitive verb followed by a direct object. "$X$ zeitigt $Y$" means "$X$ brings forth (or yields) $Y$", with the understanding that $X$ does so in or over time."\(^176\) Central to chrono-poetical analysis of technology and media culture therefore is the intransitive use: Medien zeitigen; "zeitigen here means to "time-ize" or "put in time" (2014: 406). [...] To deprive zeitigen of its direct object opens up two dimensions of "time-ing" which, taken together, drive a wedge between media time and the time of history" (ibid.).

The archaeological model of an ancient monochord becomes a *media-*archaeological object only when it is activated, that is, when the string is activated. Processual archaeology is not concerned with the human behind the artefact, but with the system embracing both.\(^177\)

Once a technical medium is intentionally activated, it starts to generate complex non-human phenomena, resulting in a media-active drama. Thereby the medium dis-closes its implicite knowledge in time.

Media archeology allows for a *synchronic* perspective or rather listening. As a *method* it concentrates on the functional-operative, processual dimension both


\(^{176}\) Geoffrey Winthrop-Young, TS "Timely Matters", 2015

in the material and in the theoretical sense. This allows for an archaeology of past media events as "re-presencing" (Vivian Sobchack), resulting in a literally better *mathesis* (understanding) of ancient technological knowledge by retro-active media archaeology.

**Radio transmission identified from within its technological infrastructures**

There are both hardwired (materially embedded) and softwired (algorithmic) structures which govern telecommunication tempor(e)alities from within. Media archaeology identifies literally anachronistic, co-existing layers of contemporary media culture. The technological infrastructure of AM radio endured for almost a century, notwithstanding cultural and discursive breakdowns and transformations. Technological standards create a temporal *epoque* of its own. As long as they are still in operation, its technical concretizations are excepted from the ephemerality of the historical event.

A German "Volksempfänger" radio (DKE) from the mid-1930s can still be operative when receiving radio signals today (applying alternating current of ca. 220 V); "analog" AM radio transmission standards have survived several historical collapses of political regimes in 20th century indeed. The new wall, rather, is digital signal processing and transmission, creating a radical "divide" from analog technique.

**Short Wave Radio**

The epistemic ground behind the telepathic notion of nonsensory perception\(^{178}\) is the propagation of electromagnetic waves, as calculated by Maxwell's equations, which falsified Newton's *actio in distans* theoreme in favor of time-based action, and were experimentally verified by Hertz' spark-gap based pre-radio transmission.

While communication studies listen to the content of electro-magnetic "Hertzean" wave propagation such as radio and television or mobile communication devices, media archaeology rather "listens" to their implicit sonicity. The task of a media theoretician now is to find arguments why, e. g., Short Wave radio communication is not an out-dated medium in times of Internet radio, and not just for nostalgics of analog technologies. Short Wave radio reception means listening not only to the actual radio program but as well listening to radio as techno-physical medium (try it, if you have an old receiver with AM / SW mode), a more media-critical and media-aesthetic transitive coupling of our ears to the technology. With its fading signal strenght and all kind of noisy interference from the ionosphere sourrounding the globe, we become aware of radio in its true sonicity: the structural affinity between technical media and sonic articulation.

\(^{178}\) See David Ray Griffin, Parapsychology, Philosophy, and Spirituality. A Postmodern Exploration, xxx
Since Thomas Alva Edison's phonograph, the analogue audio-recording media have built up a signal-based memory of sound which challenges the symbol-based traditional "musical" score as textual archive, recording even the non-musical articulations, the non-intentional, non-semantic evidence of the acoustic event, such as noise or bird-singing in the background which had been rather inaccessible for alphabetic or other symbolic notation. Wax cylinders or gramophone records constitute a sonic "counter-archive" (Paula Amad).

Once such recorded signals have been transcribed into the symbolic code, all non-musical (non-harmonic) information is irreversibly lost (unless the phonographic record itself is being preserved for later, unforseen technical "understanding").

From passive archaeological records to active media-archaeology, such signal recordings allow for the electronic measuring of sonic articulation. Instead of the predominance of musicological interpretation which is cultural semantics, this liberates the sonic event to experimentation, enabling a non-hemeneutic analysis on the sub-philological, sub-alphabetic level.

But what has been recorded on analog media is now being re-played from within the computer. With the digitization of endangered audio media, the symbolical order of clocked time sublimely returns within sound itself - which both Bergson and Heidegger denounced as "vulgar" mathematical time, mathematizing the vibrational event.

Sampling and quantizing of acoustic signals transforms the time signal into frequencies as a condition for re-synthesis. Media culture turns from phono-centric to mathematics. Digitizing analog records equals mathematical sound analysis itself. Hermann von Helmholtz questioned "mathematized" sound on the epistemological level:

"[H]ow can we be sure that what has been proven mathematically also occurs in nature [...]? [...] There is nothing in Fourier's analysis to suggest that it is litte more than a mathematical fiction, 'permissible for facilitating calculation, but not necessarily having any corresponding actual meaning in the things themselves"\(^{179}\)

In fact humans listen mathematically to the continuous sound, with our hearing channel being an implicitly calculating organ since since the inner ear counts frequencies subconsciously (nesciens, in Leibniz' term\(^{180}\)).

There is a privileded affinity between sonic resonance and the experience of past time. Ludwig Wittgenstein once confessed that when he imagined a tune recorded for a gramophone "this is the most elaborate and exact expression of

\(^{179}\) Helmholtz, *Lehre*, 56;engl. transl. xxx, 34
\(^{180}\) On the "Zählorgan Ohr" see Georgiades 1985: 42
a feeling of pastness which I can imagine"\textsuperscript{181} - undoing historicity in favor of a different access to temporality.

[Does the acoustic signal loose its temporal indexicality when being recorded? Binary "recording" on Compact Disc is a punctual temporal moment, while in acoustic recording by gramophone there is a processual time signal. Its re-play generates a different sense of the past. Replicating a sound from a recording medium, even if taken away from the real event, "retains its indexing properties"\textsuperscript{182}. As engraved index (in Peirce's semiotic sense) a sound forms a sharp contrast to its symbolic notation. Sound, when being re-generated out of electro-magnetic latency, embodies a tempor(e)ality different from the almost scriptural engraving in the gramophone groove.\textsuperscript{183} The gramophone groove is literally being in-formed by sound, but this is still a material, physical shaping, whereas digital information is no question of matter or energy any more: a sequence of symbols which can be statistically measured in terms of transitional binary entropy, a new kind of "score".]

"First sounds" (Patrick Feaster), "Time(ly) matters" (GWY)?

It is the media-archaeological intention to listen to early sound recordings in a non-historical way (non-hermeneutical \textit{Verstehen}). From this situation emanates a geninely signal-based resonance of the past based on waves and simultaneous time. It requires something like the "media-archaeological ear" to make knowledge use of that option. Phonography "avant la lettre" is understood here in its literal sense: Signal recording is pre-symbolical, non-alphabetical, no "letters".

In 1857, the Parisian printer Édouard-Léon Scott de Martinville patented his \textit{phonautographe}. Sound waves would trigger vibrations on a parchment, which would then be transmitted to a stylus which etched out the waves on a page darkened by the carbon of lampblack. Scott designed a pure inscription device lacking any playback feature, since as an expert in stenography his target was that people could and should learn to \textit{read} the graphic traces left by the mechanical acoustic transduction. Scott recorded sounds, but it did not occur to him "that by retracing the grooves and channeling the vibrations back into a funnel it could also do the reverse. "And read they were, though neither in Scott’s lifetime nor by human eyes. In 2009, almost exactly 150 years after the recordings had been made, a set of squiggles was scanned, converted into digital waveform, and played back by a computer. At first, a minor mishap occurred. The researchers engaged in acoustically disinterred Scott fell prey to Kittlerian time axis manipulation."\textsuperscript{184}

\begin{flushright}
\textsuperscript{184} Winthrop-Young 2015
\end{flushright}
"[T]hey thought they were hearing a woman’s voice, singing the French folk song 'Au claire de la lune,' but later they realized they had been playing back the audio at double its recorded speed. When they dropped it down to the right tempo, a man’s voice appeared out of the crackle and hiss: Édouard-Léon Scott de Martinville warbling from the grave."  

Today, opto-digital reading of early Edison cylinders allows for listenting again to otherwise unaccessible sound recording; the opto-digital close reading of sound as image, though, dissolves any meaningful unit into discrete blocks, which are accessible for human analysis only by operative technomathematical diagrams.

The recording which became famous by Internet circulation has been the French song "Au claire de la lune" sung into the phonautograph in 1959. But closer to the medium, the very first recording surviving as phonautogramm in the Parisean archives leads to a moment of indecidability, an irritation of hermeneutic and acoustic understanding: sound or noise? Which is the "first sound" - a recognisable artefact, or a media event? But caution, the record from which sound emanates in such acoustic argumentation is not a disc with acoustic grooves any more but a computer storage disc with discrete data sections which need algorithmic processing to become rhythmic music again.

This is an analytic, media-archaeological form of deciphering the sound of the past. To the media-archaeologically sharpened mind, such sounds from a computer audio line-out will never be confused with a "live" sound since such a mind is conscious of the algorithms of which such an animation is a technomathematical, processual function.

In media-active archaeology, the technological apparatus itself turns out to be the archaeologist proper. Patrick Feaster and David Giovannoni succeeded in re-sonifying the preserved phonautographic engravings (Schallbilder), beginning with Scott's recording of a sound folk tone of 435 Hz in the year 1859.

Here the pure vibrational medium (the sine wave again) is the recorded message, before it became buried and dissimulated in musical "content".  

150 years later science realized that with optical "reading" of such acoustic signal lines sound can be re-synthesized and thereby re-sonified.

True media archaeology starts here: The phonograph as media artefact does not only preserve the memory of culturalized sound but stores past technical knowledge as well, a kind of frozen media memory embodied in engineering and waiting to be listened to by media-archaeologically tuned ears. The noise of the wax cylinder itself which the record articulates whenever it is being re-
played is not discursive, but media-archaeological information of the physically 
real event; listening to this attentively does not exclude it by anthropocentric 
hermeneutics.

With the micro-physical close reading of sound, the materiality of the recording 
medium itself becomes archivally poetical. Instead of musicological 
hermeneutics the media-archaeological ear listens to signals. The media 
archaeologist, without passion, does not hallucinate life when he listens to 
recorded voices; the media archaeological exercise is to be aware at each 
given moment that we are dealing with technical media, not humans, that we 
are not speaking with the dead but operative recording keeps sound un-dead.

"Phonographic reproductions are physical effects of the real. A gramophone 
inscription surface captures sound waves emanating from Enrico Caruso's 
larynx. "This is not the case when we write about Caruso"¹¹⁸ - all the difference 
between transitive signal recording and intransitive historiography.

From "beyond the grave" (Chateaubriand), "[...] Scott’s Parisian recording 
session is the first undead moment in time. It is the earliest instance of 
physically recorded history we can directly link back to by means of 
technologies able to reproduce the recording. Here, media become the subjects 
of media archaeology by providing a technological link-up that enables us to 
experience a fully mechanized (and later digitized) Proustian madeleine 
moment: a temporal interface that cuts across time. [...] With the invention of 
the phonograph, he [sc. Edison] decreed, speech “has become, as it were, 
immortal” (quoted in Kittler 1999: 21). New media allow us all to graduate to 
ghosthood; but ghosts are apparitions very much at odds with history. Referring 
to Edison’s phonograph, John Peters notes that it “divides history into two 
halves, a before and an after. Prior to 1877, all sounds died” (2004: 177)."
(GWY 2015)

At that point, one step further: "Is that which is divided here, especially if it is 
divided into mortality and immortality, still contained by and within history?" 
(GWY 2015). "First, technological media record and store" - or steal? - "real 
time (with, as in case of Scott’s almost inaudible voice, all the accompanying 
noise, crackle and hiss - indeed, the very concept of noise has real-time 
recording as its technological apriori). This storage of time by means of media 
technology and its subsequent re-production by later media technologies 
allows for a direct temporal interface between otherwise distinct moments of 
human time." (GWY 2015)

But is this still a human voice, or does it turn out - resulting from analysis into 
the nature of speech by nineteenth century measuring and recording media - 
that the human voice in itself is a mechanical event which can be co-originary 
produced by synthetic devices?

Any audio recording “takes its own time. Technological media operate in 
accordance with their inner eigenzeit (“own time”), which is categorically 
distinct from the surrounding human time. “The eigenzeit of the apparatus

¹¹⁸ Geofrrey Winthrop-Young, Timely Matters. A Story of Media at Odds with 
History, typescript (November 2015)
world relates to the macro-time of history like self-referential systems to their so-called environment."189

In terms of cybernetical theory, we live in systems of closely or tightly coupled tempor(e)alities.

"Medien zeitigen, then, implies that operating in their micro-temporal eigenzeit media engage in a 'technopoiesis' of time"190 - which is chronopoetics. "They create a piece of technologically facilitated time that can be moved along outside of the human time of history and then - with ghostlike effects - be reinserted back into it." (GWY 2015)

Chronopoetics aims at replacing the unifying, totalizing signified "time" by a plurality of tempor(e)alities, as expressed by George Dyson: "Time as we know it just does not exist in the digital universe. A computer is not operating on time, it just operates on sequence. [...] this other world exists now, and it is not tied to our form of time at all."191

AURALIZATION AS RE-ENACTMENT OF THE SONIC PAST

Introduction

For centuries historical research has privileged the visible and readable archival records, thus fulfilling Marshall McLuhan's 1962 diagnosis of the Gutenberg Galaxy being dominated by eye-based knowledge.

But with auralization, a new kind of "virtual", that is: computational, simulation-based historical research has emerged: the research into past sonospheres and ways of listening long-time ago. Auralising makes random acoustic signals audible within a computer-modelled spatial surrounding.192 This algorithmic tool has mostly been applied for the design of new, that is: not yet existing concert halls, or for the restauration of still existing halls. But in the interest of historical research even the acoustics of rooms which exist no more can be derived from auralization on the basis of computer-based simulation - with all the epistemological ambivalence of "(re-)construction".

Already with the arrival of the phonograph the question arose if soundscapes for the time previous to Edison can be reconstructed. With auralization, a new kind of "virtual" (that is: numerical, simulation-based) method has emerged: the research into past sonospheres and ways of listening long-time ago. An extended notion of sonic heritage emerges from auralisation as re-enactment of the sonic past and acoustic simulation as historical method.

190 GWY 2015, referring to Ernst 2012: 286
191 This has been expressed in George Dyson's lecture "No Time Is There: The Digital Universe", on occasion of the conference Time and the Digital Universe within the festival MaerzMusik, Berlin, Haus der Berliner Festspiele (March 12 / 13, 2016)
192 As defined in Weinzierl 2002: 20
Methods of exploring the sonosphere of ancient Greek theatres by application of measuring technology have been developed long ago. In the meantime, audio communication has extended its research methods to re-enactments of ambisonics of the past - be it historic concert halls or other architectural spaces and even pre-historic landscapes. Thereby a veritable acoustic media-archaeology is emerging where the term "archaeology" is more than just a metaphor for digging for new records from the past. The paper discusses in case studies its technological means and the kind of new cultural knowledge which stems from that approach. Hermeneutic chances and limits of such re-auralization as new form of historical method and research are being discussed.

To what degree can auralization (sonic simulation based on measurement) provide a new kind of algorithmically synthesized record - and can this record still be called "historical"? Can the strict criteria of what is defined as historical record (German "Quelle") be applied to ephemeral settings like sonospheres? Here a double meaning of "record" is implied: the traditional textual document in symbolic (alphabetic) code, but recently signal recording of time-varying signals as well. There is a new possibility for tele-communicating with the past, embodied and transmitted in the acoustic records and channels.

As a result of media culture since nineteenth century, the traditional range of text-based, symbolic records of the past has been supplemented by auditive and visual signals. Acoustic signals are defined as time- and/or space-varying physical quantities. In the context of signal processing, not arbitrary on-off-signals but only (analog and digital) signals that are representations of analog physical quantities are considered as signals - thus necessarily always being embodied in the material world which remains from the past. To what degree can such an ephemeral time-varying signal like sound be reconstructed? Sounds from the past are commonly associated with recording media like the Edison phonograph. In a more active sense, media-archaeology of past sonospheres implies the technologically active agency of reconstruction, with the measuring media and signal processing methods (impulse response) themselves being the active archaeologists.

Since Edison's phonography sound, noise and voices can be technically recorded and thus memorized, resulting self-expressively in extended possibilities of sonic heritage. Research into past ways of listening have emerged in Science & Technology Studies as a new branch of historical knowledge. Here, the term sonic environment is commonly associated with industrial and other sources of noise. Complementary to the social history of such sonospheres there is a need for an archaeology of sonic expressions.

By auralization as re-enactment of the sonic past, the historical method is not

only extended but even pushed to its margins, since the temporal affect which arises from such media-archaeological auralization as "re-presencing" is different from the familiar text- or image-based historical sensations. Historical argumentation as a cognitive operation of organizing past data will never be audible but only readable in complex textual argumentation; the historical method, though, will certainly be extended to sonic articulation as well - pushing the notion of history to its margins.

To what extent is the auralization of past sonospheres a valid historical or an archaeological method of research?

The discipline of history treats the past as a sender system whose receiver are the present historians themselves - a telecommunicative dispositive. Johann Gustav Droysen who in his Historik once differentiated between records from the past which were intentionally constructed for tradition ("Quellen") and unintended records as remnants ("Überreste"). When an old building as a piece of the past is still in use, it turns out "historical" only when being perceived as such by research.  

More recently Michel Foucault criticized the discipline of history for turning monuments of the past into documents to be memorized, even if they are often of non-linguistic nature and of different enunciative qualities. He rather proposes to investigate remnants from the past by reconfiguring them into new elements - elements whose smallest units nowadays are binary digits. Even if acoustic spaces which derive from previous times are algorithmically re-sonified, they remain silent in the Foucauldian archaeological sense.

Measurement and simulation as two modes of auralization of past, therefore silent sonospheres are not historical methods per se but rather what historians call "auxiliary sciences" to the discipline of history (Hilfswissenschaften, in German).

The British historian R. G. Collingwood subsumed source-critical history under the general name of "archaeology" for which he lists "departmental sciences such as palaeography, numismatics, epigraphy, and so forth." The ambition of the present paper is to add auralization to this list. "These archaeological sciences are a sine qua non of critical history. They are not themselves history; they are only methods of dealing with the sources of history" (ibid.). "They form, as it were, the bones of all historical thinking."

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196 Johann Gustav Droysen, Historik, edited by Rudolf Hübner, Munch / Berlin (Oldenbourg) 1937, 37
197 Introduction to his Archeology of Knowledge, xxx
198 "Outlines of a Philosophy of History" (manuscript 1928), in: Collingwood 1946 / 1993: 426-496 (490)
199 Collingwood 1946 / 1993: 491
In its narrative discursive form, "[H]istory itself must be flexible, but it must have rigid bones [...]. [...] the concreteness of history can only be reached through the abstractness of the archaeological sciences" (ibid.). Collingwood in fact describes the archaeological method in terms which can be applied to auralization as well: "The archaeologist feeling his way towards new advances is constantly asking himself whether this or that detail [...] can be proved characteristic of a certain date or a certain origin" (ibid.).

But without historical imagination (usually supplied by philosophy of literature), inquiries into the past remain poor, Collingwood insists. Inbetween now a rule-governed kind of scientifically controlled imagination has emerged: digital simulation and modelling.

The unprocessed data provide the archaeological material upon which historiography might be based: "As historical evidence, records are largely unconscious, and not slanted for the consumption of posterity. In this they are therefore akin to the vast majority of archaeological artifacts". At that point, algorithmic data processing comes in - the computer as active media-archaeologist.

Auralization method has been proved to be capable of reproducing predicted room acoustical properties: "When listening to the auralization and comparing to dummy head recordings in the same position in the same room, the differences are hardly audible. The auralization technique has matured to such a level, that the human ear can hardly tell whether it is a simulation or not. From that an ambiguity of a different kind arises: Uncertainty in human judgement about the validity of an acoustic record concerning a "historical" room. If echoes and reverberations are simulated correctly, "the auralizations from simulations actually sound more natural than the auralizations using the measurements the real room". Such hyperreal (in Jean Baudrillard's sense) Verunsicherung is well known from an ancient sonospheric setting itself as described in Homer's *Odyssee* - the acoustemic challenge embedded in the Sirens' song with its turning the notion of human singing upside down: "Some have said that is was an inhuman song - a natural sound (is there such a think as an unnatural sound?) but on the borderline of nature, at any rate foreign to man; almost inaudible [...]. Others suggested that it [...] simply imitated the song of a normal human being, but since the Sirens, even if they sang like human beings, were only beasts [...], their song was so unearthly that it forced those who heard it to realise the inhumaness of all human singing."

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201 Jens Holger Rindel / Claus Lynge Christensen, Room acoustical simulation and auralization. How close can we get to the real room?, keynote lecture at WESPAC 8 (The Eighth Western Pacific Acoustics Conference), Melbourne, 7-9 April 2003, Manuscript No. 1025], chap. "Conclusions". On the approximative reliability of room-acoustical simulations, see as well Weinzierl 2002: 143 f.
202 Rindel / Christensen 2003, chap. "Subjective Verification"
Here, a methodological provocation emerges. Acousticians have a different judgement of the validity of aural simulation than historians. When soundscapes of the past ("auditory cultures") are being reconstructed by historical research, they become nothing more or less than an extension of the historical method - a new "auxiliary science" for historians. Soundscapes of the past are thus integrated (if not subjected) to the discourse of historiography - with terms like "history of sensory perception" (claimed e. g. by Karl Marx and Walter Benjamin).

While the discourse of history as cognitive dimension is bound to writing acts (or oral narrative), auditive evidence (as archived in the past) asks for an alternative approach: media-archaeological re-enactment, leading to a different temporal regime of auditory memory. Media archaeology, which is media studies as exact science, analyses media-induced phenomena on the level of their actual appearance, that is: enunciations in Foucault's terms. In our context this is physically real (in the sense of indexial) traces of past articulation, sonic signals which differ from indirect, arbitrary evidence symbolically expressed in literature and musical notation.

**Knowing past sonospheres before Edison**

The traditional *a priori* of the Humanities has been extended by signal-recording and signal-processing media which preserve and transmit what has previously been unaccessible to experience and thereby to understanding in historiography and as history. A different reality of the past is memorized by media which can register more than simply what only exists in writing or in narration - such as the noise of the battles and the sonic effects of artillery.204 A Phonograph actually registers the acoustic events.

In his novel dating from 1880, *L'Eve Future*, Vielliers de l'Isle-Adam lets the inventor of the phonograph, Thomas Alva Edison, lament on the loss of sonic information which has been lost in world history as long as this cultural memory was indeed reduced to what could historiographically be written down by the alphabet alone: "Voici tantôt soixante-douze siècles [...] qui, d'ailleurs, à titre de précédent immémorial, controuvée ou non, eût échappé à toute phonographie."205

Technical repeatability of recorded sound leads to the option of an almost a-historical sonic re-enactment of the past. But this "archival" approach comes to its limits when research is interested in sonospheres which have never been intentionally be recorded at all such as the acoustics of concert halls from long time ago. At that point, auditory evidence splits into physical and historical. The experimental approach to the reconstruction of auditory perception in the past is a method familiar from sciences: to *actually re-enact* the sound-generating setting. When we pull the string on a monochord in its subsequent intervals we

205 1880 / 1979: 34
actually experience the technical dispositive which has been the Pythagorean basis for musing about music and mathematis in the past - invariant towards entropic, historical time.206 In fact, the vibration of the string short-circuits us with that past, undercutting the "historical" divide inbetween.

**Delayed presence: Micro-tuning of space and time-reversal in acoustics**

"Time machines" are frequently associated with movie-like time travelling such as in H. G. Wells' novel. But it is rather sound and music which allow for the most flexible and dynamic time travelling: a kind of uchronia rather than utopia.

Musical performance is a time machine indeed which on the basic level allows for time axis manipulation on the time-critical micro-level like electroacoustic delay lines or electromagnetic tape delay in early electronic music studios for phase shifting and superposition of sound events.

From the microsonic field of samples up to the macrosonic domain of a musical composition, sound can be sculpted in time.207 Jacob Kirkegaard's installation *AION* acoustically unfolded the abandoned space inside the forbidden zone of the collapsed nuclear plant of Chernobyl in the Ukraine.208 In each of the abandoned rooms, Kirkegaard made a recording of 10 minutes which he played back into the same room, then recorded this again - to be repeated up to ten times. As the layers got denser, each room slowly began to unfold a drone with various overtones. Kirkegaard's sonic time layering explicitly refers back to Alvin Lucier's installation *I am sitting in a Room* (1969) where the technical set-up created a tempor(ality) of its own.

Space can be explored by time-critical sound operations; the engineering of room acoustics by measuring operations such as pulse-response (developed by Walter Sabine around 1900) has even been extended to auralization as re-enactment of the sonic past. Architecture is not just an empty vessel to be filled by arbitrary acoustics; the sound is rather been actively processed by the architecturally defined space itself. Spatial extension thus turns out to be the medium of temporal delay, while at the same time space itself becomes a function of temporal measuring. But it takes the memory capacity of an electronic device and its computational processing to provide fugitive sound articulation with a recurrent index of temporal depth - a sonic phenomenon of immediately passed / past tempor(ality).

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208 DVD, created for his MA degree at the Academy of Media Arts, Cologne, January 2006; see http://fonik.dk/works/aion.html
Audio and vision belong to separate spatio-temporal worlds; bringing them together is not possible without doing violence to their tempor(e)alities. The hearing apparatus is much more sensitive to micro-time-critical processes than the eye. While the flickering of an electric bulb (50 times/sec.) can not be noticed by the after-image in the eye any more (the cinematographical effect), the rising of acoustic pitch from 50 to 100 oscillations/sec. are very well perceived indeed. "History" commonly refers to emphatic, narrative time scales. But there is a micro-history in every sonic event which is a time-signal by definition.

There is a difference between time-based concepts like "cultural history" and time-critical micro-histories based on time signals - smallest run time differences (intervals) between direct sound waves and reflected sound waves in terms of Delta-\( t \) as remarked by Aristotle in his treatise On perception as to metaxy. Acoustic signal delay makes "the inbetween", in fact: the medium channel sonically opaque. Theater architecture, in terms of its time-critical acoustical feature, becomes "media theatre" in its truest sense: to metaxy as run time difference. Binaural acoustics turns out as implicit time-measuring instrument.

This difference (not remarked as long as the reflection is so fast in small distance that it is for human ears indistinguishable from the original direct schall) amounts to perceptible (and in terms of music halls and audio technology even disturbing) echo effects as soon as the distance amounts to perceptible wave propagation (ca. 330 meters / sec. for sound waves in the air - depending on temperature).

It is by such time-critical measuring methods (impulse response as tool for the analysis of room-acoustics) that spatial models can be constructed, such as with the simulation software EASE. If the acoustic beam is micro-chronologically traced back to locate a listener position, micro-historiography is at work. Spatial order is thereby reconstructed from time-critical pattern.

Recorded sound is temporarily suspended from fading out and thereby becomes time-shiftable in replay, thus escaping historical time. Sonic events evolving in time might even be time-reversed by immediately sending them back to the source, as long as they propagates without losing too much energy to heat consisting of the random motion of individual air molecules instead of their collective movement in the sound wave.

More than just a metaphor: Acoustic archaeology

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209 Michel Chion, Audio-Vision. Sound on Screen, Columbia UP 1994
210 See section "4.1 Temporal structure of the sound field" in Weinzierl et al. 2014
211 See Aristoteles, Über die Wahrnehmung und die Gegenstände der Wahrnehmung, in: same author, Kleine naturwissenschaftliche Schriften (Parva Naturalia), Stuttgart (Reclam) 1997, 47-86 (76, § 446b)
Let us differentiate between the socio-cultural respectively "collective" (Maurice Halbwachs) memory of sonic events (auditory memory) and the actual (media) recording, measuring and simulation of sonic articulation from the past.

In the research group around the journal *Explorations* and especially in the *Culture and Communication* seminar at the University of Toronto the psychologist Carl Williams borrowed from E. A. Bott the notion of *auditory space*. The phrase was not only metaphorically electrifying, but Marshall changed it to "acoustic space" as the quality of electronic communication spheres.²¹³

For an archaeology of the acoustic in cultural memory the human auditory sense does not suffice. The sonic trace can rather be tracked with genuine tools of media studies which is technical media themselves. One way of "acoustic archaeology" is to play a musical partition on historic instruments. But the real archaeologists in media archaeology are the media themselves - not mass media (the media of representation), but measuring media which are techically able to decipher physical signals, and representing them in graphic forms alternative to alphabetic writing since sound is articulation in time: the oscilloscope, or by numerical auralization.

Traditional archaeology - associated with digging artefacts from the past in sand and earth - is performed by humans. Let us rather focus on technologies themselves as new kind of archaeologists of acoustic and sonic phenomena. Electronic autopoiesis here becomes an argument: What has been electro-acoustically created, can be re-created by virtual archaeology, such as the *Virtual electronic poem* (an audiovisual 3-D projection) reconstructing Edgar Varèse's *poème électronique* installed once at the Brussels World Fair 1958 in the afterwards deconstructed pavillion designed by Le Corbusier and Xenakis.²¹⁴

The immersive environment developed in The Virtual Electronic Poem makes the remarkable aspects of the Poème experience accessible again half a century after the event, thereby phenomenologically annihilating the difference in terms of time; the "historical" distance at least becomes massively condensed. When it comes to recorded signals instead of printed alphabetic records from the past, re-play becomes possible by techno-mathematical means. What historical research demands here is a differentiation between reproduction, simulation and emulation as known in retro-computing.

Let us separate mere functional emulation from simulation which includes the precise micro-temporal characteristics or the original as well - which is crucial when it comes to reconstruct past sonospheres. Lowenthal terms *emulations* as "respectful yet creative reworkings of earlier forms and styles [that] transcend mere copying" and views an emulation of past artefacts as an on-going and

²¹⁴ The *Virtual electronic poem* has been installed at Medienkunsthaus TESLA, Berlin, in January 2006
evolving acticity that is always of its time but yet an essential original feature persists in all the variations and derivatives. "A reincarnating simulation seeks to bridge the ever changing gulf between past and present [...]." 215

**Archaic sonospheres**

Is there an option to catch the authentic visual of sonic gesture previous to the age of technical recording media, the phonograph, the Welte-Mignon recording piano, and cinematography? The historical performance practice (for dance, theatre and music) can not only be reconstructed by scriptural sources, or indirectly by re-using ancient hardware - be it historical architecture, or historical music instruments 216. The sonosphere itself waits to be re-sonified by acoustic archaeology.

Archaeoacoustics and sonic archaeology as ways of making acoustic properties of the cultural past "understandable" have been established as proper academic disciplines by now. Past sonospheres ask for a media archaeology of the acoustic - with digital media themselves being the active archaeologist. Digital Signal Processing and computer-based tools like wave field synthesis (which media-archaeologically recaptures Christiaan Huyghens's approach to the nature of sound propagation) and other technical dispositives now allow for the virtual (which is: digitally computed) reconstruction of "historic" acoustic spaces.

One can only tentatively re-create the soundscape of past cities like Berlin around 1900. But by measuring remaining rooms by acoustic beams 217, one can digitally render back the acoustics of architectural spaces such as ancient Greek theatres. 218 Even if media-culturalized ears may have been tuned differently since, there is a acoustic tempor(e)ality which endures in Henri Bergson's sense. Once technically recorded, sound is equipped with an "historical index" (Walter Benjamin's term) which transcends the purely historicist chronology. The positivist illusion of simulating past acoustic space is deferred by the more difficult task of reconstructing acoustic time: time-tuned sound. Such a sonosphere refers a) to the surrounding space and b) to the sources of sound, f. e. early music instruments.

**Auralization of Teatro Olimpico, Vincenza**

216 See Peter Donhauser, Elektrische Klangmaschinen. Die Pionierzeit in Deutschland und Österreich, Wien - Köln - Weimar (Böhlau) 2007
217 See the media art work *Echo Rotation* by Robert Schwarz and Emad Parandian, exposed at the Ars Electronica festival in Linz, Austria, September 2009
218 On the "musical" tuning of ancient Greek theatre architecture, see François Canac, L'acoustique des théâtres antiques, Paris (Centre national de la recherche scientifique) 1967
A test case for the epistemological gap which occurs between discovering the sonic dimension as new kind of historical source and its simulation is the reconstruction of the acoustic condition of Italian Renaissance theatres by auralization. This form of audio communication with the architectural past is no understanding in the hermeneutic sense, but first of all a co-original reset.

The Teatro Olimpico in Vicenza (opened in 1585) is preserved until today (even if not in the original condition) and are thus radically present (enduring) in terms of architecture to the contemporary spectator and listener. Still it is characterized by what by definition constitutes the past as archaeological site: the absence of humans - the audience which once filled the theatre in its performative meaning. The sonic retro-projection of listening subjects (receiver positions) based on impulse response measurements appropriate for auralization therefore is an additional virtual information. "Only an acoustical reconstruction of the historical conditions including the effect of the audience would give reliable evidence of the original performance conditions."

Acoustic information derived by measurement is archaeological evidence, but only by subsequent simulation of the occupied state this information turns into a "historical" one. If such auralization is computationally folded upon a reconstruction of the original theatre which itself is a computer model, a new kind of historical imagination emerges which transcends its data-archaeological source base. The epistemologically critical qualitative jump occurs exactly between the measurement of physically given spaces and the simulation of virtual sonospheres. Reverberation times for the unoccupied case of the theatres under analysis are derived from the measurement, while impressions for the occupied case are derived from the non-human, software-based simulation of human presence. Here, the differences between measuring of real conditions and simulations oscillate: empty room versus occupied condition (including a partial reconstructin of the historical state).

Different from historical imagination which tends to fill the lacunae in the archived sources, a disciplinary virtue of archaeology is the transparency of uncertainties. An impulse response in the Teatro Olimpico for a central source and receiver position can be reproduced, but the simulation reaches its limits when it comes to correctly reproduce a cluster of simultaneously arriving reflections from complexly structured surfaces which in fact make the "historical" identity of the concrete room - the individual material fingerprint.

The Teatro Olimpico integrates elements known from Roman theatre design into a large and reverberant enclosed space. From the room acoustical measurements according to ISO 3382 a remarkable conclusion can be derived:

"With reverberation times of more than two seconds and speech transmission indices (STI) close to 0.5 even for the occupied condition, modern standards of theatre acoustics with their predominant focus on speech intelligibility seem inappropriate for buildings of this period. Their acoustical properties along with their reception as documented by historical sources, instead, strongly supports the notion that theatres of the 16th and early 17th century have to be equally, if not primarily, considered as musical performance spaces. They represent the
Renaissance concept of a theatre of antiquity to be reborn in buildings based on antiquity, and anticipate elements of the new genre of the opera emerging at the same historical point in time.\textsuperscript{220}

The strategic link between the auralization of the Palladio theatre in Vincenza and sonic media archaeology is in its "musical" conclusion: The measurements revealed the prevalence of the musical performance part in such Renaissance auditoriums which were closer to the ancient concept of the theatrical choir (and Monteverdi’s early forms of opera) than to the speech-focused modern theatre.

In terms physical room acoustics, speech transmission in the Vincenza theatre - concluding from the measurement results - seems deficient, but literally sounds different taking into account the cultures of articulation and listening in its contemporary moment. Only the coupling of measurement data and its derivative simulation with the textual archive turns media-archaeological research into an historical argument. Respecting the numerous preserved reactions to the opening performance of \textit{Edipo tiranno} in the Teatro Olimpico, all sources underline the positive overall impression of the performance space properties. "They also give evidence of the importance of the musical part of the theatrical performance" (ibid.) and its acousmatic effects, since the instrumental effects turned out from behind the stage. Whereas the the choir was acting on stage, the musical instruments were not located in the orchestra space in front of the stage, but inside the backstage scenery, providing for a soft and gentle sound. "With respect to the instrumental parts, Angelo Ingegneri, stage director of the opening performance, reports that after the curtain had fallen to the ground in front of the stage, an instrumental and vocal music, the sweetest one may imagine, and at the same time equally soft, would begin to resonate from behind the stage. It appeared as if it would resonate "from far away".\textsuperscript{221}

Here the new quality of supporting evidence provided by historical records is revealed by auralization - a research method which differs from the traditional text- or score-based archive: "The duration of the purely instrumental parts is unknown, since no score is preserved" (ibid.).

Since the Teatro Olimpico stands for the idea of an ancient theatre to be literally reborn, the musical composition, with its predominant focus on text intelligibility and a subordination of instrumental parts, anticipates elements of the opera which emerged only a few years after the opening of the Olimpico such as known from Monteverdi. "That the Teatro Olimpico provided appropriate acoustical conditions for this new theatrical genre seems clearly confirmed both by contemporary reports and by the acoustical data of the current investigation" (ibid.) - thus mirroring re-enactment idea of "Renaissance" both in the macro-temporal (cultural history) and micro-temporal (auralizing) sense, short-cutting the "historical" distance.

Operative auralization is able to "tunnel" the temporal difference which

\textsuperscript{220} Stefan Weinzierl, Paolo Sanvito, Frank Schultz and Clemens Büttner, The acoustics of Renaissance theatres in Italy, forthcoming in: Acta Acustica united with Acustica 2014 (Summary)

\textsuperscript{221} Quoted in Weinzierl et al. 2014
separates the present observer from the situation in the Renaissance past; a temporal *momentum* flashes which can not be grasped by macro-temporal concepts like "history" or sociological terms like "collective memory" any more, but rather constitutes a short-cut between present and past - a *resonating interval* in terms of McLuhan who apparently got this expression from Werner Heisenberg's quantum mechanics. Computer-based acoustic modelling here acts as virtual archaeology, allowing for an acoustic time travelling. Next to simulating life and physics in laboratories as practiced in nineteenth century science, the experimentalisation of the sonic past emerges. This is by no means a metaphysical assumption, but based on the most physical techno-mathematical computation.

"Re-enactment" of past sonospheres (Collingwood)

The "musical" conclusion of both case studies in the exploration of past sonospheres leads to a final re-entry of the discussion of such operations for historical sources. Even for the most critical historian, musical temporality is of a specific nature which requires precise reconstruction of historical contexts but at the same time transcends the supposed historical distance which separates the present from the Renaissance past, as expressed in R. G. Collingwood's methodological *Idea of History*: "re-enactment". The sonic sphere allows for a temporal time-tunneling in a special way since it consists of time matter itself.

The rehearsal of a musical piece from the past transcends the unique location of its score in archival time (what Walter Benjamin called "historical index"). Collingwood's notorious claim that historians have to "re-enact" the past event partly derives from his astonishment that a present performance of a musical piece composed at some earlier time can still be understood at all. This requires that the auditor performs it again in imagination. Different from historical imagination in its literal visual sense, "the *sine qua non* of writing the history of past music is to have this past music *re-enacted in the present*". This practice of re-presencing (well known in its technological equivalent as hardware and software replication and emulation in Retro Computing culture today) escalated in audio recording media such as the phonograph. A gramophone disc, according to Günther Stern's (*alias* Günther Anders) habilitation thesis *The musical situation* (submitted in 1929/30 but rejected by Theodor W. Adorno), does not reveal an acoustic image of the *Mondscheinsonate*, but the *Mondscheinsonate* itself - just like the radio does not reproduce speech and music, but actually displays them (as argued by

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224 As quoted in Reinhard Ellonsohn, Der andere Anders. Günther Anders als Musikphilosoph, Frankfurt/M. (Peter Lang) 2008, 64
Adorno\textsuperscript{225}). Auralization, in a further escalation of re-presencing the sonic past by algorithmic means, finally provides archival silence with sound.

Time-based signal processing media share with musical performances the power of generating the real-time affect of presence\textsuperscript{226} - while at the same time undoing its transitive experience by the repeatability of any acoustic record. Sonic temporality thus turns into technical sonicity.

**Challenging historicity: the "musical situation"**

When artistic research deals with past musical practices, many performer-scholars consciously seek to recreate it. What actually has passed, is the unique acoustic embodiment of a musical composition in performative human variances, and the tuning of ears by musical theory. But musically (in terms of composition), there is no "historical" past at all. According to Stern's inquiry on the relation between music and historical time, when listening to music "one falls out of the world"; nonetheless, "even in this hiatus, one remains in the medium of time".\textsuperscript{227} There is an a-historic momentum of experiencing time in listening to music (the aesthetic affect) and in experiencing presence-generating devices (chrono-phenomenological aisthesis): "Musikalische Zeit ist nicht geschichtliche."\textsuperscript{228} Listening to music is a non-historic form of being-in-time.

Humans, once actively coupled to a technical music instrument, are subject to its temporal Eigenwelt. Such a scene where humans and machines meet, in cybernetic terms, is a system.

Genuine sonic media theater, though, is a further escalation. A past musical performance is usually associated with the human performer. But there are musical performances which are rather operative for not bodily but machinic implementation. While a theatrical drama (time-ordered action) from the past can be re-enacted by humans (which is always individual performative re-interpretation), music machines do not re-interpret but re-operate, in equiprimordial repetition of the musical (symbiolic) or sound (signal) event. This is, then, no historical quotation or re-call, but a time-shift of the same class of sonic event.

**Epistemogenic things: Listening to the monochord**

\textsuperscript{226} See Hans Ulrich Gumbrecht, Production of Presence. What meaning Cannot Convey, Stanford, Calif. (Stanfort UP) 2004
\textsuperscript{227} Stern 1930, as quoted (in English translation) in: Veit Erlmann, Reason and Resonance. A History of Modern Aurality, New York (Zone Books) 2010, 325
\textsuperscript{228} Günther Stern, Typescript *Die musikalische Situation*, State Library Vienna, 1930/31, 46; now edited by xxx Ellensohn: xxx
There are epistemognic things like the setting in a laboratory which is the dispositif for knowledge to emanate. In reverse, from a media-archaeological point of view, there is (technologified) knowledge materialized, embedded and implemented within operative media themselves which deserves to be extracted and derivated by explicit academic inquiry and theoretical verbalization. There is, e.g., the phonisches Rad as element in the otherwise optically oriented electro-mechanical image transmission Nipkow system.

The electro-magnet “phonetic” wheel (inside the apparatus) is meant to synchronize the image lines here between transmitter and receiver - a kind of tuning by resonance. The sonic is rather implicit here (with no sound to be heard), as implicit chrono-technical sound knowledge (sonicity), while visible tuning here takes place with the stroboskopic disc (attached to the Nipkow disc) which is on the front side (“Interface”) visible to the user parallel to the actual television image. The message of the medium process is timing here.

When Pythgoras’ experiment with the monochord in the 6th century B.C. is re-enacted today, that is: when such a string is mechanically sub-divided and activated, the techno-physical insight of the relation between integer numbers and harmonic ("musical") intervals which once led Greek philosophers to muse about the mathematical beauty of cosmic order in general is re-enacted. The experimenter certainly is not in the same historical situation, since the circumstances, even the ways of listening and the psycho-physical tuning of contemporary ears, is different. But still the monochord is a time-machine in a different sense: It lets the present share, participate at the original discovery of musicological knowledge, since the repeatable is the co-original.

In the Italian rebirth of such ancient knowledge, Vincenzo Galilei undertook a number of experiments with a lute to investigate the nature of musical harmonics - a kind of media-based archaeology of the acoustic: "Galilei employed the lute here not as a musical instrument but as a piece of laboratory equipment [...]" Once within experimentation time, it can be re-enacted. On the diagrammatical level, the re-enactment is time-invariant; on the operative level of implementation, the materiality of the medium itself seems to impose certain vetoes rooted in the historicity of the instrument, but in fact, the epistemological operation remains intact in principle (that is: archaeologically): Claude V. Palisca set out to replicate this experiment using a

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230 E.g. the Nipkow-Televizor (30-line), produced by the Tratri Novakove Company in Prague, 1934, on display in the 60 Years of Television Broadcasting special exhibition at the National Technical Museum, Prague, May-December, 2013

231 Martin Heidegger, Sein und Zeit, xxx, 385: "Die Wiederholung ist die ausdrückliche Überlieferung, das heißt der Rückgang in die Möglichkeiten des dagewesenen Daseins."

lute built in the 17th century by an unknown maker. "The present condition of the instrument required the use of some substitutions for the materials originally used by Galilei in his experiment; however, these did not affect the basis tenets of the experiment."\(^{233}\)

Once human senses are coupled with a technological setting, phenomenal experience is captured within its temporal field, in an autopoietic chrono-regime with its specific dynamics (or mathematics, when data are registered digitally). Such couplings create moments of literal ex-ception: Man is taken out of the man-made cultural world (Giambattista Vico's definition of "history") and confronts naked physics.

In Martin Heidegger's late philosophical work, the fundamental notions of being (Sein) and time (Zeit) converge in the notion of the event (Ereignis).\(^{234}\) In this double sense, the experiment allows a unique experience and at the same time for communication across the temporal gap (bridging a temporal distance. In the processual moment of the re-enacted experiment, one shares the same temporal field (a notion which implicitly refers to the episteme of electromagnetic dynamics).

Can such experimentation be extended to macro-temporal eventality as well? Experimentation does not give access to historical experience, since past culture can not be re-enacted (except in experimental archaeology, maybe). This is the argument of historians usually applied to differentiate their hermeneutic discipline from the natural sciences. At the climax of historicism in Germany, Hermann von Helmholtz doubts the possibility of re-enacting ancient musical experience; research has to refer to its symbolic, indirect representation (so-called "history of music") instead, since direct observation and experimentation is not possible any more, and the mind which is trained in modern musical listening can not be open for previous, archaic ways of listening.\(^{235}\)

But with re-programmable tools of research, in the meantime, media-archaeological experimentation (simulation as opposed to historiographic historicism) gives access to the invariant elements of knowledge in time indeed: as a kind of "experimentalisation of history" by simulations, allowing to short-cut the historical distance, since ancient knowledge of music begins to

\(^{233}\) Claude V. Palisca, Was Galileo's Father an Experimental Scientist?, in: Paolo Gozza (ed.), Number to Sound. The musical way to the scientific revolution, Dordrecht / Boston / London (Kluwer) 2000, 191-199 (195)


\(^{235}\) "Die Beziehung auf die Geschichte der Musik wird [...] auch deshalb nötig, weil wir hier Beobachtung und Experiment zur Feststellung der von uns aufgestellten Erklärungen meist nicht anwenden können, denn wir können uns, erzogen in der modernen Musik, nicht vollständig zurückversetzen in den Zustand unserer Vorfahren, die das [...] erst zu suchen hatten" Hermann von Helmholtz, Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik [*1863], Braunschweig (Vieweg) 1913, 411
become re-enacted by computing which is an implicitly "musical", algorithmic technology itself.236

BETWEEN PHYSICS AND INFORMATION: AUDIO RECORDINGS FROM THE PAST AND THEIR TEMPOR(E)ALITIES

Technical recording vs. symbolic transcription

Since the invention of the phonograph, the analogue audio-recording media have built up a signal-based memory of sound alternative to the symbol-based archive of musical notation. A collection of wax cylinders or gramophone records is rather a "counter-archive"237 of sonic memory in the sense of Henri Bergson's and Edmund Husserl's emphasis on the human form of temporal experience, which is affective rather than clock-like integration. Signal-based records constitute a different kind of memory than the alphabetical scores which constitute the traditional "audio" archive.

Long time ago, an early Greek adaptor added single symbols for vowels to the known Phoenician alphabet for the purpose of making not only the rough content but the very musicality of oral poetry explicitly recordable. But even this advanced notation inspired by the Muses is still symbolic, like the score transcriptions which Béla Bartók provided for Milman Parry's recordings of songs by Yugoslav singers of tales on aluminium disc. What these discs were able to record, though, was not only oral poetry itself but the non-musical articulations as well. This acoustic supplement extends even to non-intentional, non-semantic evidence, such as noise or bird-singing in the background or the singer's coffing during performance - information which might be important for a realistic interpretation of the circumstantial conditions of oral poetry. Acoustic media both keep and reveal a mémoire involontaire of past acoustics which was never intended for tradition - a noisy memory, unaccessible for symbolic notation in the traditional sense.


237 Paula Amad, Counter-Archive. Film, the Everyday, and Albert Kahn's Archives de la Planète, New York / Chichester (Columbia University Press) 2010, 153. The phonographic equivalent of Kahn's cinematographic project have been the Archives de la Parole, founded by the linguist Ferdinand Brunot in 1911 at Sorbonne University, Paris
Different from transcriptions into scores, technical signal-recording of musical articulation allows for the electro-physical measuring of recorded events by "sampling". This enables a non-hermeneutic analysis of cultural articulation on the sub-philological, sub-alphabetic level.

**Entropical and negentropical sound memory**

Analogue recording media consist of two bodies. There are two complementary approaches to the conservation of analogue audio carriers. The one cares for preserving the physical, especially chemical and electro-magnetic properties of the concrete media body - since all media technologies are hardware in the first place. The other, sometimes opposing approach is to preserve media-based memory as information, up to the extreme point of view that the material body might be abolished after its essential transcription into its pure binary information units. "We no longer collect the carriers, clay tablets, books or floppies, just the information." But to which degree does the archival authority of an audio record still depend in its material physical embodiment? Is it no longer important by which carrier one generation passes on its information to the next?

Soon after the emergence of photography as the oldest analogue signal-based medium in the technical sense, in 1859 Oliver Wendell Holmes pointed out the symbolic trade between information and materiality: "From now on, form is separated from material. In fact, the material in visible objects is no longer of great use, except when being used as a model from which the form is constituted. Give us a couple of negatives of an object worth seeing ... that's all we need. Then tear the object down or set it on fire if you will ... the result of this development will be [...] a massive collection of forms that [...] will have to be [...] placed in great libraries."

Indeed, once the mechanically engraved sonic signals on material carrier (phonograph) or magnetically embedded (magnetophon) has been transformed into binary code, it can be (virtually lossless) "migrated" from one computing system to another.

Archival endurance in preserving the sonic heritage thus is not achieved in the traditional way any more (which used to be monumental fixation), but requires repetitive dynamic refreshing. In the early days of digital computing technological storage devices like the mercury delay line and the Williams Tube resembled the human memory mechanism in its predominantly "regenerative" character between the passing and the repetitive. From this derives a fundamental change in the philosophy of how to secure media-archival data for future use. In such machines, memories are dynamically permanent (no oxymoron); they are constantly refreshed so that either their ephemerality endures or random access allows for immediate change.

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238 Tjebbe van Tijen, We no longer collect the Carrier but the Information, interviewed by Geert Lovink, in: MediaMatic 8 No 1/1994, xxx
239 Quoted from: Wolfgang Kemp, Theorie der Fotografie I (1839–1912), Munich 1980, 121
240 Wendy Chun, xxx
Such repetition of the identical differs from the variable mechanism of oral tradition, such as Homer’s epics across the "dark" centuries without writing. But such pre-technological variation (rather "cultural technique") itself became evident only by signal recording. Bartók comments on occasion of his transcriptions of phonographic recordings: "Folk-songs are a living material; and [...] subject to perpetual changes, preserving constancy only of certain general formulae. [...] the same poem has been recorded from different singers, in order to show what are the [...] traits depending on the individual singers, and what are the permanent ones, beyond the personality of the singer."²⁴¹

["In musical notation, time signature denotes the basic unit of time duration in a measure of music manuscript and describes how many units constitute the measure [...] thus ordering the spacing of bar lines that in turn delineate rhythmic units" (Foster). Doch "[t]here are no time signatures in Bartók’s or Erdely’s transcriptions (excluding Ugljanin’s gusle solo) because, presumably, the guslar's rhythmic and melodic phrasing has no precedent for those who would read the transcriptions. [...] time signature broadly suggests musical form [...]. In his transcriptions of South Slavic epic song, Bartók faced the challenge of interpreting rhythmic groupings that had no archival body of traditional (art music) reference."²⁴² Even if Bartók's transcription is an accurate notation of the performance event, "it inevitably falls short of recording every aspect of Ugljanin’s art. For example, Ugljanin holds the second half of beat 3 in the third measure of the introductory gusle solo slightly longer than one half beat. Ugljanin’s exclamation “Ej!” at the start of the voce part (measure 1) is longer than one beat. There is a point beyond which we fail to reproduce completely any performance event" (ibid.).]  

Material media are marked by their individual degree entropy and characteristic probabilities of physical endurance. The Eigenzeit of physical media differs from the software-based media by embodying fundamentally different temporal regimes. Bartók optimistically commented the media memory conditions of the phonographic recordings of oral poetry made by Parry: "The records are mechanically fairly good [...] Aluminum disks were used; this material is very durable so that one may play back the records heaven knows how often, without the slightest deterioration. Sometimes the tracks are too shallow, but copies can be made in almost limitless numbers."²⁴³

But physical recording media are subject to macro-temporal entropy - known as the chemical deterioration of Edison cylinders and magnetic tapes. Digitized signals at first sight resemble the tradition of music notation, but are endowed with operational activity; they are algorithmically executable. Symbolic techno-

²⁴¹ Bartok op. cit.
archival permanence is almost time-invariant, sublated from change, leading to ahistorical immediacy in the moment of re-play.

**Phonography versus magnetophon: Electronics makes a difference**

[Technical sound carriers do not just replace each other in an evolutionary course of technology. The phonograph respectively the gramophone record on the on hand, the magnetic record on tape on the other, and finally the digital recording represent fundamentally different materialities and essences in terms of their technological registering of time-variant signals, time-based forms of reproduction and their function as time-channel in individual communication alias cultural tradition. In the case of phonography versus magnetophone, electronics makes a difference. The magnetic (audio) tape’s logics diverges from phonographic linear inscription and rather connects to "non-linear cultural techniques (splicing, looping, dubbing)" and affording a "consistent interface with telephony, radio". In that sense, the tape acts "as counterpoint to the process of inscription at the foundation of the phonographic regime"244.]

In May 2011 two Black Boxes could finally be rescued from the ground of the Atlantic sea two years after the Air France aeroplane crash: the data recorder and the voice recorder keeping the last words of the pilots in the cockpit but as well the background noises which retrospectively signal the unfolding desaster. The recordings proved to be miraculously intact. Both data recorders consist of memory chips which keep their magnetic charge, different from mechanically vulnerable previous recording media. Whereas mechanical records still represent the culturally familiar form of physical impression (writing), electromagnetic latency is a different, sublime, uncanny form of insivible, non-haptic memory. The voices and sounds emanating from such a black box are radically bodiless, generating a different temporality than the familiar historio-graphical time.

Sound recording does not simply unfold as evolutionary course of technology in history, but the phonographic record on the on hand, the magnetic record on tape on the other, and finally the digital recording represent fundamentally different materialities and logics (literally techo/logy) in terms of their ways of registering time-variant signals, time-based forms of reproduction and their "archival" being in time. The electronic tube, especially the triode, once liberated technical media from mechanical constrains, thus: from erasure over time; still the tube or transistor are subject to decay over time themselves. Entropy in the second law of thermodynamics (Ludwig Boltzmann) states that the energy circulation of any closed system tends to an uniform equilibrium. In technomathematical communication theory (Claude Shannon), the term has been reversed to measure the degree of information. Negentropic persistence against entropic time ows its ahistoricity rather to its different form of registering the physically real acoustic event not by signals, but by binary symbols.

244 As expressed by the editors Andrea F. Bohlman / Peter McMurray, Tape: Or, Rewinding the Phonographic Regime, in: Twentieth-Century Music 14/1 (2017), special issue Tape: Or, Rewinding the Phonographic Regime, 3–24 (8)
The difference between mechanical and electro-magnetic audio recording is not just a technical, but as well an epistemological one. While the phonograph belongs to what Jules-Étienne Marey once called the "graphical method" (analog registering of signals by curves), the magnetophone is based upon the electro-magnetic field which represents a completely different type of recording, in fact a true "medium". What used to be transitive, invasive writing into a storage medium like the wax cylinder has been substituted by the electro-magnetic field, but writing nowadays re-turns as digital encoding in different qualities. Sampling and quantizing of acoustic signals transforms the time signal into frequencies as analysis and as a condition for re-synthesis (Fourier analysis and synthesis). The Technical Committee of the IASA in its standard recommendations from December 2005 points out that digitization of analogue sound carriers from the past does not necessarily mean a loss of information about the signal, but can in fact grasp the physical signal as information much more precisely than former analog recording where non-linear distortions of the signal in the process of technological transcription frequently take place. The Nyquist / Shannon theorem already fixes that with a sufficient sampling rate the original signal can be truly reconstructed; for archival needs a radical over-sampling up to 192 kHz does not just keep the blunt sound information, but the memory of noise (scratches) as well. Nevertheless, digitalization means a radical transformation in the ontology of the sound record - from the physical signal to a matrix (chart, list) of its numerical values. Media culture thus turns from phono-centrism to mathematics.

A counter-archive? Acoustic archaeology

There is a distinctive difference between so-called "social" respectively "collective memory" of musical events and the actual media recording of sonic articulation from the past. For an archaeology of the acoustic in cultural memory the human auditory sense does not suffice. Let us, therefore, track the sonic trace with the genuine tools of technical media. One such way of "acoustic archaeology" is to play a musical partition on historic instruments. But the real archaeologists in audio archaeology are the media themselves: measuring devices which are able to de-cipher physically real signals and to represent them in forms alternative to alphabetic writing, resulting in sinusoidal articulations in time, operative diagrams such as being indicated by the oscilloscope.

Media-active archaeology can be applied to past sound, generating a different kind of audio-archive. When listening to "ancient" recordings from Edison wax cylinders, nowadays being restored with technomathematical software as digital re-production of sound, we might ask with Michel Foucault (in a slightly different context): message or noise?

245 See http://www.iasa-web.org/IASA TC03/IASATC03.pdf
246 Michel Foucault, Message ou bruit? [*1966], in: same author., Dits et Écrits I, Paris 1994, 557-560
Today, opto-digital reading of early Edison cylinders allows for listening again to otherwise unaccessible sound recording; the opto-digital close reading of sound as image, though, dissolves any meaningful unit into discrete blocks, which are accessible for human analysis only by operative technomathematical diagrams. This is a truly analytic, media-archaeological form of deciphering the sound of the past. It requires a media-archaeologically tuned ear to make knowledgable use of that option as an alternative to the cultural emphasis on musical semantics. To the media-archaeologically sharpened mind, sonic articulation visible on a computer screen will never be confused with a "live" sound since such a mind is conscious of the algorithms of which such an animation is a technomathematical, processual function.

At that point, the archival operation extends from restauration and conservation to re-animation and thus becomes a true media-archaeological operation. In a novel called *Time Shards*, the science fiction author Gregory Benford imagines a research laboratory which reconstructs "fossil voices" out of the grooves of mediaeval pottery.

In media-active archaeology, the technological apparatus itself turns out to be the archaologist proper. Patrick Feaster and David Giovannoni succeeded in re-synonifying phonautographic diagrams preserved from pre-Edison times, beginning with Léon-Scott’s recording of a sound folk tone of 435 Hz in the year 1859. This self-referential (and auto-poietic) memory of sound technology itself is as worth to be preserved for eternity as any other more articulate cultural sound (the ethno-musical sources). With a dela of 150 years science fianlly realized that with optical "reading" of such acoustic signal lines sound can be algorithmically re-synthesized, and all of the sudden the children's song "Au clair de la lune, Pierrot répondit" (recorded by Lèon-Scott on April 8, 1860 in Paris) resounds again.  

What has been metaphorically described as the pick-up of sound images by a "virtual, digital gramophone needle", in fact is something media-epistemologically different, a picking-up of a completely new kind: digital sampling.

As the primary scene of sonic media memory, almost immediately after its invention, the Edison phonograph was announced in the journal *Scientific American*. It obviously triggered phono-archival phantasms (in the Romantic tradition of the historian of the French Revolution Jules Michelet, who in early Nineteenth century believed to hear the murmurs of the dead in the archives), as a true Lautarchiv: "That the voices of those who departed before the invention of the wonderful apparatus [...] are for ever stilled is too obvious a truth; but whoever has spoken or whoever may speak into the mouthpiece of the phonograph, and whose words are recorded by it, has the assurance that his speech may be reproduced audibly in his own tones long after he himself has turned to dust. [...] A strip of indented paper travels through a little

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247 [Hear](http://www.firstsounds.org/sounds/1860-Scott-Au-Claire-de-la-Lune-09-08.mp3)

248 [Harald Haack, Die erste Klangaufzeichnung. Eine Audiografie, online](http://newsbattery.blogspot.de/2008/05/07/die-erste-klangaufzeichnung-eine-audiografie)
machine, the sounds of the latter are magnified, and our great grandchildren or posterity centuries hence hear us as plainly as if we were present."²⁴⁹

Natural language is evasive, liquid, in itself unrecordable beyond the bodily range, but technical media (different from alphabetic phonetic writing which "freezes" the human voice into a range of a very limited symbolic code) are able to de-freeze recorded voices in almost all frequencies by re-play. After two millennia of supremacy of the phonetic alphabet there are new kinds of cultural technology in sound recording.

There is a record in the Vienna Phonograph Archive of emperor Franz Joseph I of Austria-Hungary written deep into the wax cylinder (a recording from Bad Ischl, 2nd August 1903). At this point, you probably expect me to play this recording. There is a reason why I don’t, since I want to prove that sound recording has already developed a true media memory which differs from the remembrance of its content. The experiment is very simple: Please imagine yourself the phonographic recording of His Majesty’s voice. I am sure that whatever you think the timbre of his voice sounds, you will acoustically hallucinate as well the scratching, the noise of the recording apparatus.

True media archaeology starts here: The phonograph as media artefact does not only preserve the memory of cultural semantics but stores its own past technical knowledge as well, a kind of frozen media memory embodied in engineering and waiting to be listened to by media-archaeologically tuned ears.

One step further in the experiment, emperor Franz Joseph’s actual statement can be quoted. Significantly, this statement - which is one of the first voice recordings preserved at all - turns out to be the pure message of the medium. When a new technical medium emerges humans are very aware of its technicality (which afterwards, when it becomes mass media, tends to be forgotten in favor of so-called "content"). The emperor expresses his joy to literally "incorporate" his voice into the Vienna phonograph archive.²⁵⁰ Indeed we are able, today, to listen to human voices which exterminated hundred years ago, by applying laser reading of the wax cylinders which do not destroy its source in the act of re-play. But once more, what we hear is not only the message (the emperor’s enunciation) but as well noise (the phonographic scratch). That is what the medium tells us. The noise of the wax cylinder itself which the record articulates whenever it is being re-played is not discursive (cultural) but media-archaeological information of the physically real event. Let us listen to this attentively and not exclude it hermeneutically like in the proverbial Cocktail party effect of auditory communication between humans.

With the micro-physical close reading of sound, the materiality of the recording

²⁵⁰ "Es hat mit sehr gefreut, auf Wunsch der Akademie der Wissenschaften meine Stimme in den Apparat hineinzusprechen und dieselbe dadurch der Sammlung einzuverleiben."
medium itself becomes archivally productive. Complementary to musicological hermeneutics the media-archaeological ear listens to the poietics of signals.

Different from passive symbolic writing systems like the phonetic alphabet which still require the human mind and imagination to become "alive", the power of signal-based technical media lies in their ability to actively (re-)create real presence. Let us quote once more from Bartók's comment on his transcriptions of recordings of Yugoslav oral poetry from the 1930s: "It gives you a thrilling impression of liveliness, of life itself" <op. cit.>.

Media as active archaeologists

All of the sudden, audio recordings are not just archival objects any more, but media decoders become active archaeologists of past sounds themselves.

The frozen voices on the analogue, vulnerable storage medium of wax cylinders are currently being de-freezed by digital means. The Berlin Society for Applied Informatics has developed a method to gain acoustic signals from negative traces of galvano-copies from Edison-cylinders by opto-endoscopic „reading“ - scanning visual information into sound. Making stored acoustic waves actually sound does not demand rhetoric imagination but on the contrary a hermeneutically distant ear, an exteriority of interpretation which only the aisthesis of the opto-technical scanner can provide. Technical media provide a different option of reading: listening without (premature) understanding. The archaeological ear tries to mimick this ascetic confrontation of signals, resisting the narrative temptations.

With the media mystery of the recordability of the physically real of sound and images, humans get a multi-media mirror effect (in Lacan´s sense), sublating the clear-cut difference between presence and absence, present and past. It is possible, today, to listen to music-ethnographical play-backs in almost exactly the same quality as the natives once experienced in the past. Only the media-archaeological operation of opto-digitally reading the inscribed traces makes the otherwise unaccessible sound recording audible again. We can see a spectrographic analysis of an ancient sound recording - a straight look into the archive.

New options of sound retrieval

The notion of the sound archive is in transition. As long as there have been symbolical, score-based archives only, the phantasma of recording the

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253 Spectrogram of a digitally reconstructed recording of Wedda songs from Ceylon 1907 on http://www.gfai.de/projekte/spubito/index.htm
acoustically real (predominantly the human voice) has generated imaginary forms of memorizing sound in supplementary ways.

The reanimative reading of texts encoded in the vocal alphabet has for long times privileged the prosopopoietic desire to actually experience" the voice of the dead. The textual *gramophone* ("sonic" vowels as letters) inevitably belongs to the realm of the symbolic which is the order of the archive, different from the immediacy of the physically real, indexical trace: tracks of sound on recording media (analogous to rays of light fixed in photography). This new kind of sonotechnical memory is "archive" or "library" no more. Phonographic records, though being signals, were still submitted to the symbolic order of alphanumeric metadata: inventorization and administration which were developed in the long-time context of paper-based archives. But with the necessity of digitizing phonographic records in order to preserve them against physical, media-archaeological entropy, a new epistemological option emerges which deserves media-theoretical attention. "Listening with algorithms" are methods known from commercial IT and copyright audio identification already, but may be reapplied within Digital Humanities to engage with sonic materials in creative ways to unlock audio archives by sonic analytics.²⁵⁴

Media archaeology points out the discontinuities which arose with the inclusion of audiovisual records in traditional archives, libraries and museums in the twentieth century, resulting in a rethinking of the options of retrieval under digital media conditions. Search operations such as similarity-based sound retrieval transcend the notion of the archive itself by the technical and cultural application of stochastic order out of media-immanent signal disorder. The archival digitization of analog sound carriers from the past, which mostly results from the pragmatic impulse to preserve endangered cultural heritage, at the same time invites for rethinking the organization of such digitalized records. A different kind of aesthetic and cognitive options unfolds in the mathematicized sonosphere itself, liberated from the traditional archival metadata restrictions, towards a truly media-immanent navigation within the sounds of the past.

²⁵⁴ See the project "Humanising Algorithmic Listening" (HAL) at the Sussex Humanities Lab, http://algorithmiclistening.org, accessed 14 February, 2019