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Abstract / Introduction

As much as the symbolic musical code differs from analog signal recording (and its digital sampling), the institutional archives of musical composition differ from the technical *l'archive* (in Foucault's sense) of sound production. The archival memory, and tradition, of music used to be dependent on cultural techniques like alphabetic writing, and musical notation. But in the epoch of technical media, the essence of the technical *l'archive* behind sound production is not "archival" in the sense of a memory institution any more. Down to oscillators from which sound emanates by an assemblage of transistors, condensers, and resistors, the circuit diagram (and its actual implementation) functions as new kind of "archival record", and media archaeology - rather than cultural historiography - is the appropriate method for their investigation.

The technologies behind electronic sound recording, storage, processing and distribution represent a radically standardized, new "archive". In its digital regime, mechanical instrumentation, and the bodily performance, are replaced by intellectualized computing. What is articulated here are the variances of techno*lógos* itself, as an encounter of material entropy with the symbolical order. With its algorithmization, the "archive" not passive any more, waiting to be activated by human composers and musicians, but becomes media-active, coupling the human user to its proper temporalities. The discrete timing of data processing in computing is a return of muscality from within technology: "algorhythmics" (Miyazaki), and its programming as an equivalent to the musical score.

The algorithmization of the musical archive extends to new forms of exploring technically recorded sound from the past. While the symbolic order of musical scores - its musico*lógos* - is (ideally) "timeless", the physical materiality and ephemerality of sound, and sonic (media) art, are subject to temporal entropy. This results in divergent strategies of technical preservation.

Behind the Archive: *l'Archive*

In his analysis of memory systems, Klaus Krippendorff differentiates between memory involving records, which depend on (at least intermediary) fixation of records worth of remembrance (archival storage), and almost memoryless reverberating circuits (dynamic storage). But in administration there is a third form of memory at work: structural memory.[1] The analysis of such a functional, embodied memory, in times of media culture, points to the technological condition itself, to its techno-archival

1 Klaus Krippendorf, Principles of Information Storage and Retrieval in Society, in: General Systems vol. 20 (1975), 15-34

infrastructure. Radical media-archaeological analysis shifts the focus of attention to this "archive behind the archive" that is the technical infrastructure and its techno*lógos*. This kind of archive, e. g., is the clock signal distribution network *inside* the Central Processing Unit within computers, which is responsible for the time slots which characterize time-discrete computing as such. Such a micro-archival infrastructure is "hard-wired" temporality.[2] This requires less a cultural analysis of musical archives, but rather an analytic attention the techno-logical episteme.

L'archive, in Foucault's sense, does not mean the sum of all the texts that a culture has kept to record its administrative becoming, nor "the institutions, which, in a given society, make it possible to record and preserve those discourses that one wishes to remember and keep in circulation"[3]. With his knowledge-archaeological focus on operational statements, Foucault understands archival materiality - and its corresponding protocols - as a regulatory process operating in an enunciative function.[4] The rule of materiality that statements necessarily obey is therefore of the *non*discursive "order of the institution rather than of the spatio-temporal localization; it defines possibilities of reinscription and transcription (but also thresholds and limits), rather than limited and perishable individualities"[5]. Foucault's *Archaeology* focuses less on "the atomic statement [...] but the operational field of the enunciative function and the conditions according to which is reveals various units (which may be, but need not be, of a grammatical or logical order"[6]. It is from here that the techno*lógos* unfolds.

In French, the institutional state archive is expressed by the collective term *les archives*, while in Foucault's neographism, *l'archive* in the singular, signals a different meaning. Concerning musical memory, *l'archive* does not refer to the great repository of musical scores, sequences of musical notations "that translate in visible characters thoughts" - and compositions (the *lógos* of music) - "that were formed in some other time and place"[7]. Foucaults neologism rather refers to the density, and pace, of culture-technical, and nondiscursive, "practices, systems that establish statements as events (with their own conditions and domain of appearance) and things (with their own possibility and field of use [...] that I propose to call *archive*" (ibid.) - such as the musical code, and sonic wave forms. "The archive is first the law of what can be said, the system that governs the appearance of statements as unique events. But the archive is also that which determines that all these things said do not accumulate endlessly in an amorphous mass" (ibid.). The conventional musical archive, in terms of scores and other documents related to composition, "collects the dust of statements that have become inert once more, and which may make possible the miracle of their resurrection" (ibid.), while signal replay from the sonic archive derives from operations like phonography. *L'archive ,* in its more technical sense, is rather "that which defines the mode of occurrence of the statement-thing; it is *the system of its functioning*" (ibid., italics M. F.) - the operative diagram.

Can the Archive of the Present be Observed?

The tempor(e)ality of the Foucaultean archive is delicate. The current technological *l'archive* can hardly be observed immediately from within (unless by real-time hardware and software hacking), since in the present, access is usually protected from the side of the manufacturers.[8] "The analysis of the archive, then, involves a privileged region: at once close to us, and different from our present

2 Kyle Stine / Axel Volmar (eds.), Hardwired Temporalities, forthcoming at Amsterdam University Press (Recursions series)
3 Michel Foucault, The Archaeology of Knowledge and the Discourse on Language, translated from the French by Allan M. Sheridan Smith, New York (Pantheon Books) 1972, 129
4 Adrian Mackenzie, Machine Learners. Archaeology of a data practice, Cambridge, MA (The MIT Press) 2017, 158
5 Foucault 1972: 103
6 Foucault 1972: 106
7 Foucault 1972: 129
8 See Friedrich Kittler, Protected Mode, in: idem, Draculas Vermächtnis, Leipzig (Reclam) 199xxx

existence, it is the border of time that surrounds our presence, which overhangs it, and which indicates it in its otherness; it is that which, outside ourselves, delimits us."[9] That is what research-librarian Eivind Rossaak calls "the time-bomb-effect", where observations into the (slightly past) contemporary technical archive "attains a stronger aesthetic and knowledge forming quality much later, delayed"[10].

[The Recursive Archive: Trance Map]

While the creative use of digitally archived musical (symbolic notation) and sound (signal recording) resources frequently relates to sonic semantics, and musical affect as cultural content, a more radical media-archaeological analysis is focused on the techno-logical condition for such usage, storage, distribution, and aesthetic affordances at all: *l'archive*, in Foucault's sense.

If recorded sound is creatively ("mis-")used beyond its original context, it is media-actively *dearchivized* - such as Evan Parker's music as source material when it is manipulated by the musician himself, and Matthew Wright, to create new works. This is the case with the recording of *Trance Map* in 2008 and 2009. The final album has been released in 2011 (by the Record Label Psi); its co-composition from both human, and nonhuman actors, is mixing "field recordings, samples from cassettes, turntable scratching and the live processing of Evan's relentlessly evolving saxophone lines"[11]. While Parker is still playing soprano saxophone, in addition, he plays samples from his collection on LP, cassette or CD, while Wright instrumentalizes turntables, computer and software in live sampling and sound design. As Parker says of Wright, "His facility with the various DSP [digital signal processing] programs used *totally blurs the distinction between playing, mixing and editing*"[12], resulting in one continuous piece of music. "The introductory section consists of small sounds that could be samples of insect noises or their electronically-generated equivalent" (Eyles).

Case Study: Vintage Computer Sound Chips

The experimental, and media-forensic, investigation of vintage computer sound chips is, first of all, related to a familiar archival function indeed. The condition for the re-enactment of media-generated sound from the past is the radical presence of its records. The specifications of archaic Programmable Sound Generators (PSGs) "can be found in their data sheets and in literature of the time which has been stored in internet archives"[13]. Such records have been assembled by retro-computing enthusiasts distributing this information, "so that today anyone can work and program with vintage PSGs" (ibid.). But the accessability of their *l'archive*, in the techno-mathematical context, differs from the meaning of a public, or "open access", online archive as the symbolic order of administrative memory.

Since the end of the 1970s, the first explicit PSGs did not simply anticipate the later sound cards in terms of computer history, but their integrated circuits in gaming consoles and home computers embodied a rather pre-historical alternative. Their "programmability", with its explorable options in the symbolic order, can be media-archaeologically considered as an archive of the virtual. In its strict techno-mathematical sense, the "virtual" is defined as time-objects which come into existence by computation only. In the co-originary production from both the human programmer, and the coded

9 Michel Foucault, The Archaeology of Knowledge and The Discourse on Language, New York 1972, 130
10 Electronic communication by Eivind Rossaak (National Library, Oslo), February 7, 2020, regarding Cori Arcangel's retro-computing installation *Super Mario Cloud*
11 http://www.matt-wright.co.uk/trance-map, accessed 30 January, 2020
12 As quoted in: John Eyles (reviewer), https://www.allaboutjazz.com/trance-map-evan-parker-psi-review-by-john-eyles.php, accessed 30 January, 2020
13 Stefan Höltgen, Play that Pokey Music: Computer Archeological Gaming with Vintage Sound Chips, in: *Computer Game Journal* vol. 7, pp. 213–230 (2018); https://doi.org/10.1007/s40869-018-0068-5, section 5

hardware as co-agency, this allows for a kind of techno-sonic "re-presencing"[14], which is different from collected, passively sampled, and merely played-back recorded "sound objects" (in the sense of Pierre Schaeffer). A media archaeology of sound that emanates from early microcomputers can still be directly confronted with its objects of research and is not limited to the historiographical situation of writing about it in the past tense. "Operative PSGs are not historic objects; they are open to current experimentation and thus reveal that their actual sounds are far from the average features described in data sheets. Rather, they oscillate in inaudible micro-temporalities, situating their sounds in time [...]. Behind their audible outputs, inaudible signal events are processed, stored, and transmitted in strict processor clock-time" (Höltgen 2018, section 7 "Sounds of Silence"). The output of the programmable sound generator, which is experienced by human hearing, only represents the surface of the implicitly sonic events that occur within the computer as their techno-archival apriori. "How can we get an idea of this cacophony?" (ibid.). The programmability of PSCs is both conditioned, and limited by the actual hardware, which embodies a techno-logical system. The technological *l'archive* consists of both hard- and software, equally comprising "musical" algorithms and "sonic" signals. The special method to trace its specific processual ontology is " a computer archeological question about the untimeliness of computer sounds" (Höltgen, 2018, section 1).

Media archaeology radically investigates the encounter of the symbolic order with the mateReal. Just like conventional musical score notation "freezes the volatile character of sound onto paper" (Höltgen 2018, section 2), the SID chip for Commodore 64 home computers (e.g. the MOS 6581) "only exists on paper, and only this paper chip shapes the specifications and frames for possible functions that are called its normal values. The sound production of a real SID chip depends on many (chip-)external parameters [...], most of which were not even known to and thus not documented by its inventors" (Höltgen 2018, section 2) - which is the archive in latency. "This raises the question of how one can theorize about real functions of media at all. To tackle this issue, computer archeology uses a kind of archaeography [...], a notation system for technical operation: their demonstration."[15]

Vintage PSGs not only actively call to mind the beginning of game sounds, but also unmistakably speak for themselves every time they are in operation. Retro sound is nothing more or less than the impossibility of not hearing the technology" (Höltgen 2018, section 7). The sounds which emanate from computer chips cannot be reduced to the physical laws of acoustics. They are as much dependent on their technically implicit condition, which is not an acoustic one like in familiar instruments. Such sounds are as much governed by their electronic, internal environment, as much as they are controlled by the musician, from the interface outside. To describe this *l'archive* , an archivography is mandatory. While a simply discursive description of such sound processes will only give an impression of its average or ideal state, "[a] proper notation would be done in a hardware-orientated programming language" (Höltgen 2018, section 2).

The design of early sound chips, and their generation of wave forms, has either be preconditioned by the analog synthesizer premise, or, less audio-culturally, from the point of view of the engineer. Vintage sound chips like the TIA (Television Interface Adapter), the POKEY (POTentiometer KEYboard integrated circuit), and the SID (Sound Interface Device), first of all, by their very binary signal nature, generate square waves. The techno-mathematical archive of such sounding (their digital sonicity) is the logics and architecture of binary computing: bit-music and Hardware-Sounds. "The square waves of the 1-bit sounds did not only allow for the production of music; even speech (and singing) could be generated and played back with this technology. While the unpleasant musical 1-bit sound output of early home computer games appalled gamers, it simultaneously impressed them when

14 Vivian Sobchack, Afterword. Media Archaeology and Re-presencing the Past, in: Erkki Huhtamo / Jussi Parikka (eds), Media Archaeology. Approaches, Applications, and Implications, Berkeley / Los Angeles / London (University of California Press) 2011, 323-333

15 Höltgen 2018, section 2. See Moritz Hiller / Stefan Höltgen (eds.), Archäographien. Aspekte einer Radikalen Medienarchäologie, Berlin (Schwabe Verlag) 2019

their computer suddenly started to talk" (Höltgen 2018, section 3). At that moment, techno*lógos* becomes literal. 1-bit "music", as it is cultivated in the retrocomputing scene, as a monophonic pulse-frequency-modulation, directly derives from the techno-logics of binary computing. The notion of "implicit sonicity", different from explicit "sound", names vibratory (sine wave) or rhythmic (square wave) articulation which is generated from within the techno-logics of electronic circuitry. Implicit sonicity is not addressed to human musical cognition, but function to the machine, such as the ultrasonic mercury delay line which has been used as intermediary RAM in early computing.

Once a technological device is not anthropocentrically reduced to the cultural archive, but when it is discovered in its essential autonomy, it turns out as *l'archive*, where its technology reveals an implicit nonhuman knowledge. From the technology of vintage sound chips, a remarkable bandwidth of both actual, and virtual, explicit (sonic) and implicit (sonicity) idiosyncrasies arises. Symbolic analysis may deal with its intentional musical purpose, but it fails when it comes to listen to the actual sound of such electronics, in its unintentional implicit sonicity. Such actual sounds cannot be identified by a merely textual analysis; the ideal typology differs from their actually sounding. For electronic PSGs and the technical frames which support their sound generation, even "an emulation can only be an idealistic or average approach to them" (Höltgen 2018, section 6). In emulation, the media-epistemic friction that occurs when the symbolic meets the real, is revealed. By emulating vintage computers, they can be museologically (so to say) explored without invading the original device and the risk of its material damage. When it comes to their sounding features, however, none of their actual features is made audible by an emulator; "it is just a sound sample" (Höltgen 2018, section 5). Emulators are programmed to simulate a symbolic machine, but a simulation turns out "insufficient when it comes to physical hardware functions. With sound functions in particular, this becomes noticeable: The Commodore emulator VICE offers several versions of the SID chip [...] and emulates them down to their transistor level, but it cannot possibly emulate their analog filter technology" (ibid.).

Sound arises from within computing technology even without the soundchip, such as in the bus wires and its unintentional signal cross-talk. "In order to reduce costs, the data bus of the C64's VIC-II graphic chip was not shielded properly. In operation, it transmits electromagnetic fields, especially when it comes to the horizontal sync signal to the SID's data bus [...], producing an audible high-frequency noise" (Höltgen 2018, section 5). At that moment, techno*lógos* becomes articulate. Such disturbances are used creatively in media artistic sonification, which is "speculative (techno-)realism" in the media-archaeological style. There is implicit "sonicity" in electronic technologies[16], such as a couple of functional oscillators, which were never intended to produce musical sound at all. The best media-archaeological listener to such implicit sonicity is electronics itself, such as the Elektrosluch detector. This open-source hardware device has been designed to audify digitally coded electromagnetic signals - just like a short wave radio receiver when its antenna is placed close to a high-frequency computing device. By placing the Elektrosluch directly onto the SID sound chip of the Commodore 64 home computer, its surface musical tunes and sounds, which served early computer games, are replaced, or overplayed, by its "subface" sounds which are constantly generated by the SID with its discrete sound-alike 1-bit sounds (square waves) as source of the actual "music" as diegetic element in the computer game.[17]

Fig.: The "Elektrosluch" measuring and sonifying the electromagnetic field emitted by the Commodore 64 sound chip SID while processing a computer game melody. (c) Stefan Höltgen"

16 See W. E., Sonic Time Machines. Explicit Sound, Sirenic Voices and Implicit Sonicity in Terms of Media Knowledge, with a Preface by Liam Cole Young, Amsterdam (Amsterdam University Press), series *Recursions*, 2016

17 Höltgen 2018, section 7, referring to Frieder Nake, Das doppelte Bild, in: Bildwelten des Wissens. Kunsthistorisches Jahrbuch für Bildkritik, vol. 3 (thematic issue "Digitale Form", ed. Margarete Pratschke), no. 3 (2005), 40-50 (47)

Beyond Heideggers's "question concerning technique"[18], radical media archivology "reveals" the techno-*logical* archive behind electronic sound generation - be it analog, or digital. The technical act of archivization produces as much as it records the event.[19] This archival techno-logics is not limited to the symbolic regime of coded, textual, nor musically notated information. Hidden PSG features are not only explored on the level of their software (i. e. programming techniques); the soundchip hardware as well has been hacked and used in creative ways. Since the notorious SID chip has become a rarity since its production expired in the 1990s, some retro-computationalists have reverse-engineered the chip in order to build surrogates using Field Programmable Gate Arrays. Hereby, a new symbolic order, embodied as matter, inhabits the real of sound production again. This archive is not reduced to a merely symbolic tectonics, but becomes a technological archi(ve)tecture.

Investigative "toy computing"[20] of sound chips is "carpentry" (in Ian Bogost's sense[21]) with epistemological intention. It reveals the musical archive in the ludomusicological sense, by playing *within* a structure, as well as playing *with* that structure. "Gaming a system" is a techno-ludic attitude, which takes advantage of the accessability of PSGs in early home computer "systems" (in Foucault's archival sense) of the 1970s and -80s. Once their operative diagram (its circuitry) is sonified, instead of simply paying attention to the phenomenally intended sounds, the media-archaeological ear starts to listen to its techno-idiosyncratic articulations.

The specific affordances of such sound chips turn them into rather unconventional musical "instruments" with characteristic sonic qualities of their own. This technological *l'archive*, in Foucault's sense, not only enables, but delimits the range of possible sounds by defining what kind of articulation can be synthesized, thereby even deconstructing the hegemony of old European musical harmonics. The technical limits of early computer game sounds - their *l'archive* - "opened up when sampling (e.g. with the Paula chip in the Commodore Amiga), CD-ROM drives, and FM synthesis chips emerged. These new technologies did not lead to more characteristic computer sounds but conversely to a unity of sound in all contemporary systems" (Höltgen 2018, section 7) - a shift from hardware-conditioned sound, to symbolically coded music. "The specific tone of a system or PSG has had to disappear or move into the background to enable sound to [...] merge with the visual output and be deployed for the gamer's immersion into the game" (Höltgen 2018, section 7).

The essence of the technological sound *l'archive* is not simply technical and static, but temporal: musical (code), sonic (pulse frequencies), and rhythmic. Sound generation, in early home computers, before it became later realigned, by more efficient sound cards, to the aesthetics of the traditional system and episteme of musical harmonics again, has been, *en arché*, designed, even thought, from, and by, *l'archive* of its concrete hardware options. The implicit musicality of the embodied Turing machine infrastructure is "algorhythmic" (Miyazaki), and its implicit sonicity derives from its data processing frequencies. In musical terms, computing cannot be reduced to the clock-like meter, but its data cycling units conform with rhythm. "Machines operate and unfold with different temporal rhythms."[22] This requires a rather media-archaeological, than cultural-discursive, "rhythmanalysis"[23]. *From within* technologies, "music" returns - not in its aesthetic, but in its functional sense. When such

18 Martin Heidegger, The Question Concerning Technology, in: idem, The Question Concerning Technology and Other Essays, transl. William Lovitt, New York, NY (Harper & Row) et al. 1977, 3-35

19 Jacques Derrida, Archive Fever: A Freudian Impression, trans. Eric Prenowitz (Chicago and London: University of Chicago Press, 1996), 16 f.

20 According to Stefan Höltgen's PhD thesis *OPEN HISTORY. Archäologie der frühen Mikrocomputer und ihrer Programmierung*, submitted to the Institute of Computing Science at the Mathematisch-Naturwissenschaftlichen Fakultät of Humboldt-University Berlin, 2019

21 Ian Bogost, Alien Phenomenology, or What It's Like to Be a Thing, Minneapolis / London (Univ. of Minnesota Press) 2012

22 Levi R. Bryant, Onto-Catography. An Ontology of Machines and Media, Edinburgh (Edinburgh University Press) 2014, 158

means invite to be taken advantage of by composers, and by performers of electronic music, this is not simply a technical extension of previous human musical practices. It is rather the techno*lógos* itself which makes use of artists to be articulated musically.

Archiving the Technical *l'archive*: Re-enacting Electronic Music from the Past

In the analysis of contemporary sound composition and aesthetics, the abundant use of the term "archive" for all kinds of recycling and sampling rather prevents the insight into their technical condition (*l'archive*). But when it comes to the prospective "future in the past" of current musical media culture, and for the maintenance of what once used to be "live" electro-acoustics, the institutional agency of the archive is mandatory, as much as the museum[24], for the documentation of its technical codes, and electronic matter. Only this allows for an operative re-enactment of past sound scenarios, which requires their media-active rewiring and recoding.

With the technification of cultural memory, a shift from the passive archive to the regenerative archive goes along. For the memory of electronic music (be it analog, or digital), it is not sufficient to preserve a single performance by phonographic recording media (the passive archive), but to regenerate its technical condition, and therefore maintain its *l'archive* to enable its re-enactment again and again, where the difference it not only in the human individual performance, but in the different interpretations by the electronic machine itself. A simply recorded document (the traditional archival record) does not reveal this virtual archive any more. For such a recreation, "data archaeology, musicology, as well as the plain technical knowledge of studio equipment and sound engineering is required"[25]. The options range from using old hard- and software, emulating old machines on newer computers, and rewriting the composition with new code. But for a radical algorithmic archaeology "[a] patch for Max/MSP can easily have dozens of subpatches and in order to recode the patch it first must be disassembled and its structure understood."[26]

With regards to technologies, its archive cannot be reduced to their documentation by an external administrative enframing, but extends to *l'archive* in the sense of Foucault, or in the sense of Heidegger's *Ge-stell*. Everything in this techno-logical archive as a standing-reserve (*Bestand*) "is ordered to stand by, to be immediately at hand, indeed to stand there just so that is may be on call for a further ordering"[27]. Without ever having been explicitly registered in terms of the institutional archive, internal techno-logics transmits, and reproduces, its knowledge in equiprimordial reenactment of its logical, and physical, circuitry. This *latent* archive does not belong to the historical time order, but it installs a media-tempor(e)ality of its own.

In discrete or graphic transcription of electroacoustics, the score does no tell it all; neither does the complementary signal-oriented sound or video recording properly document the technology-based musical intentions, and allow for a re-creation of the work in a co-originary understanding. In order to re-interpret an electroacoustic composition, a tape-based record of its first live performance is insufficient in terms of its infrastructural documentation (*l'archive*). But it is adequate in terms of

23 Henri Lefebvre, Rhythmanalysis [1992]: Space, Time and Everyday Life, transl. Stuart Elden and Gerald Moore, London: Continuum 2004
24 Friedrich Kittler, Museums on the Digital Frontier, in: Thomas Keenan (ed.), The End(s) of the Museum, Barcelona (Fondació Antoni Tápies) 1996, 67-80
25 Composer Sebastian Berweck in his dissertation *It worked yesterday. On (re-)performing electroacoustic music*, doctoral thesis, University of Huddersfield (2012), 199; available at http://eprints.hud.ac.uk/id/eprint/17540 (accessed May 13, 2019)
26 Berweck 2012: 215

27 Heidegger 1977: 17

media affinity, since magnetic recording is in alliance with the technological condition of the electronic composition itself.

The Difference it Makes: Symbolical Musical Archives vs. Real Sound Storage

In cultural history, the institution of the archive is traditionally bound to textual records in the alphabetic code. Its musical equivalent is the score notation, and, more recently, the documented source code in computer music programming. With photography in the optical field, and the phonograph in the sonosphere, a new kind of "analog" cultural memory has arisen, which is not symbol-based representation any more (the alphabet), but records actual signals as the very essence of physical media processing. Fixed storage media might still be administered in terms of the library, or the archive, but this symbolic order remains external to the signal space and signal time. A new kind of "archivology" is required to administer genuine media records from within.

At first glance, with digital media, the symbolic, text-based regime seems to return again - not so much on the visual, or acoustic interfaces of computers, but from within. Computer programs are written in the alphanumeric code indeed, but different from previous texts, they are actually implemented into real, electro-physical matter such as voltage levels to embody the binary abstractions "0" and "1". Just like the musical composition requires actual embodiment to become sound, an algorithm is dependent on its material implementation as software to become an active time object.

Sound Archives and the Options Arising from their Digitalization

The digitalization of analog sound signals is its core "archival" operation in the technological sense. This is not a musical re-alphabetization, but its mathematization. Different from classical Digital Humanities, where the computer has been an extended tool to cope for human reasoning with big statistical data (such as in computational linguistics), algorithms themselves become the non-human agencies and "archaeologists of knowledge", once they are allowed to act according to their own techno*lógos*. The "cold memory" of signal recording, and the digital code, have no specific sense for what human aesthetics cognition experiences in acoustic perception. Algorithms listen to a different kind of musicality. This starts with simple analytic tools like the "Silence Finder" in the free audio software Audacity. In algorithmic techno-memory practice, the Silence Finder automatically, that is: algorithmically, tags intentional and non-intentional pauses in speech, or sound, files. Even if this tools has been developed for sound editing and opens the option of "remove" the moments of silence, it can be used as a research tool to identify, in large data banks, the moments when the enunciation hesitates - for reasons that then require, only in a second step, hermeneutic, i. e. human, context-intensive interpretation. Cultural sound archives, like the Berlin Phonogram Archive and its sister institution in Vienna, are "sensitive" not only in the ethical sense, but in being non-symbolical, non-alphabetical: signals are the most indexical "sensitive" traces of physical, here: acoustic events. New options of audio signal mining open when the digitalization of analog sound carriers is not simply an act of saving recordings and enabling them for "open access" in terms of Digital Humanities. The real opening of the media archive, in its media-epistemic sense, is the processing of audio data in terms of techno-mathematical, algorithmic intelligence. The algorithmic crawling of a born-digital, or digitalized, audio archive replaces the static classification of the traditional catalogue by dynamic access. Relational databases allow for the coexistence of different orders without destroying the material data structure itself, a kind of order in fluctuation. And random search (like "hashing" in the administration of computer storage) is the radical temporalization of order itself.

Thereby the notion of the musical archive is in transition. As long as there have been symbolical, score-based archives only, the phantasm of recording the acoustically real has generated imaginary forms of memorizing sound in supplementary ways, such as simulating the musicality of the human

voice by the vocal alphabet. Sound itself has been limited to melodic perception in the present, resulting in epistemic phonocentrism, or as "secondary retention" (in Husserl's term) from the past by human recall. But with technical recording devices, the exact repeatability of a temporal object (for which sound is its manifestation *par excellence*) has been facilitated.[28]

The reanimative reading of texts which are encoded in the vocal alphabet have 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 sono-technical memory is "archive" or "library" no more. Phonographic records, though being signals, were still submitted to the symbolic order of alphanumeric metadata; their inventorization and administration took place in the long-time tradition of paper-based archives. But with the necessity of digitalizing 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" is a method known from commercial IT and copyright audio identification already, but may be reapplied within "algorithmicized humanities", and machine learning, to engage with sonic materials in creative ways to unlock audio archives by sonic analytics.[29]

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 digitalization 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, once it is liberated from the traditional archival metadata restrictions, towards a truly media-immanent navigation *within* the sound signals from the past.

Cold Algorithmic Listening to Digitalized Sound Archives

Media-archaeological "cold listening" that uses speech or other audio features, which are automatically extracted by computer algorithms, allows for the experimental exploration of large sound collections. While the manual human assignment, and tracking of identifiers for audio, or image content in the Internet (especially with the advent of blockchain technology of peer-to-peer transactions) is time- and cost-consuming, auto-generated identifiers are created algorithmically from the content itself, as it is proposed for the International Standard Content Code (ISCC 2019). A new kind of archive arises with the computability of digitalized cultural content which circulates in the Internet, and Social Media. Even if such items have never been registered according to archival rules, algorithmic queries allow to address them, resulting in an ever-increasing *generative* archive.

Audio content identification, and acoustic fingerprinting, is not simply an extension of archival taxonomies to "machine listening", but an operation with its own *eigen*knowledge of sonic objects. From a media epistemological perspective, new forms of audio content identification open different

28 On this concept in Bernard Stiegler's volumes on *Technics and Time* see Matt Bluemink, Stiegler's Memory: Tertiary Retention and Temporal Objects, in: 3:AM Magazine, https://www.3ammagazine.com/3am, accessed February 13, 2020

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

orders of the sonic archive. A media archaeology of audio content identification reveals the technological *l'archive* governing such forms of enunciation.

For a computer, a sound file is only an array of binaries. A computer uses low-level information to "interpret" the sound. A semantic gap opens when it comes to "understand" the musicality of such audio signals. Trying to close this semantic gap is one of the motivations for using a multiplicity of features, such as detecting similarities in sound files. From that, a more formal way of "hearing" from the point of view of algorithms can be learned, which identify what a sound represents. This enriches the epistemic range of acoustic space, which has been limited so far to cultural semantics, by the *non*human ear. While musicological understanding re-creates cultural memories which are clearly addressed to the human ear, algorithmic sonic data mining provides insight into *implicit sonicity*.

Lev Manovich's software mining of big data explicitly adapts Franco Moretti's approach to hundreds of literary texts from past centuries, requiring "distant reading". What Manovich has developed in his "cultural analytics", though, is focused on visualization.[30] This may be modified for acoustic space, to "distant hearing". Most digital analysis of files from sound archives is still restricted to one piece, but large-scale digitalization projects open the option for "big sonic data" analysis. "Sensualizing" such high-dimensional data does not necessarily require diagrammatic visualization, but rather asks for ways of genuinely sonic "algorhythmization"[31].

The true impact, or media message, of digitalization, beyond its apparent audio media content, is the option of algorithmic, software-based analytics. The application of sonic data mining discovers hidden, archivally implicit knowledge, which traditional musicological research would not even ask for. Mathematical intelligence of algorithms serves for developing new strategies of audio archival findings like so-called "deep" machine learning - a set of algorithms which uses a deep graph with multiple processing layers for automated speaker and speech recognition.[32] Such a "depth" evokes the images of stratigraphic layers, but this is still not an archaeological metaphor. it is rather the pointer to a radically *operative* archaeology of sonic knowledge, which is the implementation of advanced mathematics in high-frequency computing power in a techno-mathematical alliance.

Media-archivological analysis is using software tools not for the identification of individual sound recordings but for a large, trans-individual array of sound files. In the 20th century, listeners to phonographic archives compared rather small numbers of sound records, and the use of our human cognitive capacities unaided by machines was considered to be sufficient. The number of phonographic and grammophonic records in sound collections like the Berlin Phonogram Archive has been rather individually researched so far; it is still small when compared to born-digital sound files around the globe today. This has resulted in the development of a kind of mass-statistical hearing. In social web portals like YouTube, tens of thousands of files with sonic expression are born digital as user generated content, which poses a different challenge to individual human research by its shere scale.[33] In term of Lev Manovich's computer-based "cultural analytics", there is now the option to apply computational, which is: algorithmic intelligence ("intelligence" in its twofold meanings). Listening to the digitalized sound archive in contemporary culture not only offers, but even requires, the usage of information science. The methods applied here are core operations of data science such as feature extraction, measuring distance in feature time, and dimension reduction. But if the real sound

30 See Lev Manovich, Data Science and Computational Art History, in: International Journal for Digital Art History, no. 1 (2015), 12-35

31 In the sense of Shinatoro Miyazaki, xxx

32 As described in depth in the Wikipedia entry *online* (accessed July 19th, 2016)

33 Manovich 2015: 33

archive, in that context, is not its recordings but *l'archive* in Foucault's sense, it is the underlying algorithms of digital audio signal processing tools themselves which requires critical source studies.[34]

Radicalizing the Archive: (Self-)"Thinking Infrastructures"

While similarity-based sound retrieval leaves their digital archive more or less intact, it becomes media-active archive with machine learning. The biggest challenge which arises in contemporary, and future media culture is not networks or digital infrastructures[35], but the fact that networks and infrastructures have become *active matter* in the form of artificial neural nets. This becomes a critical perspective from the position of an conventional state archive, a national library, or a cultural museum. That makes the difference to Bernard Stiegler's notion of "tertiary retention" in his *Technics and Time* argumentation, which relates to individual memory becoming technical with gramophone recording. When being looked at less from the perspective of cultural tradition (heritage and semantic "content"), which relates to so-called historical time, or the events that constitute parts of this dimension, but when considered media-epistemologically, the transformation of passive signal-transmitting, tele-communicative infrastructure into active matter, results in a kind of radicalization of the archive-in-motion thesis.[36] This change takes place *within* technology itself. Artificial neural nets, as applied in machine learning, are the epistemic playground for what will happen with the big cultural networks as such. The new *l'archive* (in Foucault's sense) is not simply the archive of archives any more, neither a passive technical storage and transmission, but actually begins to articulate its own techno*lógos*.

34 See Stephen Ramsay, Reading Machines. Towards an Algorithmic Criticism, Urbana, Chic. (Univ. of Illinois Pr.) 2011, Kap. 1 "An Algorithmic Criticism", 1-17

35 Cf. Starosielski / Parks (eds.), Media Infrastructures, and the introduction here, Bowker: https://www.emerald.com/insight/publication/doi/10.1108/S0733-558X201962

36 See Eivind Røssaak (ed.), The Archive in Motion. New Conceptions of the Archive in Contemporary Thought and New Media Practices, Oslo (Novus) 2010