"THE LOGO-TECHNICAL MECHANISM (TIME-DISCRETE COMPUTING)"

Detailled content by chapters:

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DOES COMPUTATION HAVE A SENSE OF ENDING?

Algorithmic "Being-to-Death": the *Halteproblem* of Discrete State Machines

The theory of automata deals with the production of sequences of machine states; "the *finite-state machine*, is an abstract system which has a finite set of internal states."[1] A mathematical calculation therefore is a change of the memory state of the machine. Starting from an initial state, and passing a pre-programmed sequence of intermediary states, a final state is achieved. Undisputable precondition is the algorithmic structure of the procedure, i. e. a final state must be achieved with a finite series of steps.

1 Teuvo Kohonen, Self-Organizing Maps, Berlin / Heidelberg / New York (Springer) 1995: 16; see idem, Self-Organization and Associative Memory, Berlin / Heidelberg / New York / Tokyo 1984

The computer, as it is know today, has been conceptually invented in 1936 / 37 as an answer to the mathematical *Entscheidungsproblem*. The question of ending startet the age of digital media. In mathematics, the "decision problem" is a challenge formulated by David Hilbert in 1928: the search for a general procedure which allows, within a formal system, to decide if a problem can be solved within limited time or not. Can a turingmachine decide if another one can solve a numerical problem within limited, ending (German: *endlich*) time? Such a mechanisation transforms the original mathematical, logical question into a temporally determined one, the *Halteproblem* and thereby a time-critical question - "critical" in the sense of a necessary decision.

The turingmachine (which is mechanised mathematics) is to be understood from the dynamic perspective of its temporal processuality. "The writing head of a Turing machine inscribes symbols one by one in an infinite string, giving rise to time as a sequence-stream."[2] The strict sequentiality of the turingmachine and its operational table introduces an element of intuitional mathematics contrary to Hilbert's self-referential play of symbols: the hypothesis of a temporally structured sequentiality.

Finite-state machines operate as sequences of events in time indeed.[3] Computation by humans on paper happens in uneven intervals and might be interrupted at any moment, such as a coffee break). Their technological implementation turns such stepwise operations into regular intervals. Computation performed by humans is arhythmic (in Aristoxenos' sense of prosodic *mousiké*), while its technological embodiment is based on time-discrete clocking - numerical variables for time *t*. In binary computing, these events happen as discrete moments.

On several levels, mathematical algorithms become involved in time. "Generally, *a program is only an algorithm if it stops eventually*"[4] - which is the a time-discrete variance of Heidegger's ontological *being-to-death*. Furthermore, "[o]ne of the most important aspects of algorithm design is creating an algorithm that has an efficient run-time."[5] This even extends to the past in a non-historicist sense; the art of retro computing is time-critical itself. "An optimal algorithm, even running in old hardware, would produce faster results than a non-optimal (higher time complexity) algorithm for the same purpose, running in more efficient hardware; *that is why algorithms, like computer hardware, are considered technology*."[6] - and not simply a

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2 Francisco J. Varela, The Specious Present. A Neurophenomenolgy of Time Consciousness, in: Jean Petitot / same author / Bernhard Pachoud / Jean-Michel Roy (eds.), Naturalizing Phenomenology. Issues in Contemporary Phenomenolgy and Cognitive Science, Stanford (Stanford UP) 1999, 266-316 (268)

3 Marvin Minsky, Computation. Finite and Infinite Machines, Englewood Cliffs, N. J. (Prentice-Hall) 1967, 12

4 https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019

5 https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019

6 https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019. On run time complexity of algorithms (in polynomical, "finite" time) see Thorsten Schöler, entry "Informatik", in: idem. / Stefan Höltgen / Johannes Maibaum / Thomas Fischer (eds.), Medientechnisches Wissen, vol. 2: Informatik,

mechanical procedure of algorithmic computation.

TempoR(e)alities in computation

The limits of meta-mathematical *computation* (algorithmic indecidability) have been their de/finition in the most literal sense from the beginning. For the "digital", discrete symbolic regime of computation, the axiomatic *Halteproblem* aks whether there can be an algorithm which can decide, in advance, if another operative algorithm, when symbolically performing a logical task step by step, will ever come to an end. The *Halteproblem* is practically answered by the notion of what can be "effectively" calculated. When it comes to technological implementations of an algorithm, the clock time of discrete ("digital") computing clashes with Bergson's durational notion of time indeed. Once computation is not discussed on the abstract algorithmic level but as actual implementation[7], the time axis itself turns calculation into a drama, that is: a well-defined unfolding of events *in* (as more radically, *as*) time. It is another Turing when discussing the actual construction of an electronic computing machinery (his ACE). While the materiality of the symbol inscription ("ink") deserved at least a footnote in Turing 1937, he then concentrates on the difference temperature makes for the ultra-sonic impulse mercury delay memory for Random Access Memory in a computing machine.[8]

When the media archaeological ear listens to the temporal mode of *actual computing* (instead of merely conceptual *computation*), it reveals the inherent musicality of existence in discrete states. With increasing circulation of software and "Apps" which are embedded into every day devices, society has not only become increasingly rule-governed in the logical sense, but "algorhythmicized" (Miyazaki) in the temporal sense as well.

The agency which makes all the difference between metamathematical computation and actual computing is not abstract "time", but concrete enunciations of *timing*, technological *chronopoiesis*. Time-critical aspects of actual computing such as Norbert Wiener's almost poetic notion of the "time of non-reality" which occurs between discrete switching states, points at the tempoReal of the binary techno-event itself.[9] While in abstract computation, logically nothing happens between zero and one, in electronic flipflop circuits there occurs an irreducible temporal gap, a temporal "real" in the signal flank between two voltage levels. Alan Turing defined computation as a discrete state machine with discontinuous encodings which move in sudden jumps or clicks from one quite definite state to another. But in its material

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Programmieren, Kybernetik, Berlin / Boston (de Gruyter) 2019, 7-130 (50 f.)

7 See Hans-Peter Kriegel / Erich Schubert / Arthur Zimek, The (black) art of run-time evaluation: Are we comparing algorithms or implementations?, in: Knowledge and Information Systems. 52 (2) 2016, 341–378

8 A. M. Turing's ACE Report of 1946 and other papers. Volume 10 in the Charles Babbage Institute Reprint Series for the History of Computing, 20-105

9 See Claus Pias (ed.), Cybernetics - Kybernetik. The Macy Conferences 1946-1953, vol. 1: Transactions / Protokolle, Zürich / Berlin (diaphanes) 2003, 158 f.

implementations there are no strictly "digital" machines. Even the binary "bit", as a voltage-controlled signal, moves continuously. As a matter of fact (that is, in factual materiality) there is always already "analog" movement *between* binary "digital" states.

Computing (with) time: clocked computational *timing*

Uncovering the eventuality and finiteness of being[10], Heidegger's ontological analysis of temporality is still decisively anthropocentric, and explicitly opposed to reified time as embodied in the mechanical clock as a trivial machine. But with the cultural mastering of analog electronics and high-frequency digital computing a form of processing temporal moments came into the world which unfolds a temporal *kosmos* of its own, its very own chronosphere which deserves its proper media archaeology, practicing "aufweisende Grund-Freilegung"[11]. On the micro-temporal level of electrophysical media, this is performed time-critically.

The Heideggerian analysis of being-as-time may be applied to computing indeed. Once a computing mechanism is in the (physical) world, it is subjected to temporalities - the subsymbolical, material level of physically implemented logics (mathematics). Media-ontological analysis reveals no static being, but the essential processuality of media-time (their operativity). The being of technical media is incompatible with a motionless ontology.

"Analog" computing has had a physical sense of time, different from numerical computing. In mathematics, Newton and Leibniz have developed a mighty computational tool known as differential and integral calculus in order to cope with temporal objects, notably speed and acceleration, by discrete mathematics which translates "time" into a non-temporal language which the digital computer understands. Numerical mathematics constructs discrete algorithms to cope with continual mathematical problems in two models: direct computing which after a finite temporal process delivers the exact solution, and approximation. Numerical procedures replace a continuous phenomenon by a discrete, that is: finite problem, at the cost of errors which results from the very act of quantisation such as sampling.

There has been a kind of "digital computing" *avant la lettre* which lacks a sense of ending because of its very repetitive measuring of time itself: the automated clock, driven in equi-distant pulses by the escapement mechanism, an oscillaltor literally counting (that is, *computare*) time, with a discrete sense of temporal flow. It was Aristotle, who in book IV of his *Physics* has defined time resulting from measuring movement sequentially by numbers. The countability of time (and therefore its possible mechanization) is the core of Aristotle's definition in his *Physics*, Book IV: "time is not movement, but only movement insofar as it admits of enumeration" (219b 2-3).

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10 Heidegger 1926 / 1979: 375
11 Heidegger 1926 / 1979: 8

"Interrupt"

Media-*culturally*, human-machine interaction occurs in time-critical escalations, such as computer games. The temporal constellation which has replaced the narrative, dramatic aesthetics of (tragic or happy) ending, in "ergodic" computer games[12] and human-computer interaction in general, is the techno-logical momentum of *interrupt*, where *kairotic* time replaces *chronos*. Interactive events in the system coupling of computer and human unfold in idiosyncratic time based on the "interrupt" mode of computing, rather rhythmically than algorithmically, in contrast to the computational steps that unfold within the computer itself, where instruction-execution histories express an ordering of inner events of an algorithm without any relation to the actual passage of time. "Algorithmic time is intentionally measured by number of instructions executed [...]. Operation sequences are interactive streams with temporal as well as functional properties, while instruction sequences describe inner state-transition semantics."[13]

"... else loop forever": The loop as time figure in analog and digital media

In the 1930s, the "invention" of the computer as symbolical machine occurred as a by-product of Alan Turing's effort to answer to the challenge of the computationally undecidable.[14] The question if computer programs have a sense of ending (the *Halteproblem*) leads to the more general consideration of media-induced temporality.

Media systems internally develop new forms, non-narrative operations and transformations of time-discrete of temporal sequences from within, which relieve from the dominant temporal notion of "ending". With finite algorithms for recursive functions and real-time operations, within high-frequency computing, a delicate micro-dramaturgy of synchronizations and other temporal properties unfolds on the media-theatrical scene, where smallest bits of time are "critical" for the success of the whole computational event as such.

Stil, Turing's design of a symbolical machine is an instantiation of a "limitation" in both its axiomatic and temporal sense. "Computable" numbers are those which are calculable by *finite procedures*. It is principally impossible indeed for mathematics to decide beforehand whether a complex algorithmic task will ever come to an end or not - "... else loop forever".

"Eternally" iterative loop structures have been a characteristic time figure of analog recording media already, like the classic magnetic tape (reel-to-reel). The computer program code line "... else loop forever" reminds of Samuel Beckett's play *Krapp's Last Tape* (first performed in London 1958) which ends

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12 Aarseth 1999

13 Peter Wegner, Why interaction is more powerful than algorithms, in: Communications of the ACM, vol. 40, no. 5 (May 1997), 80-91 (83 f.)

14 Alan Turing, On Computable Numbers, with an Application to the Entscheidungsproblem, in: Proceedings of the London Mathematical Society (2), Bd. 42 (1937), 230-265

with the director's note "tape runs on in silence" - an endlessness which has been answered by technology by introducing the auto-stop mechanism at the end of a tape. There is a growing asymmetry between media time, the tapes which re-play Krapp's voice almost invariant to temporal progression, whenever it is activated by the magnetophone by electro-magnetic induction, and Krapp's biological existence which is subject to entropic ageing.

The computational *Halteproblem* (among other *Entscheidungsprobleme*) searches for an algorithm which can decide, if programs, or automata, will ever stop in case of certain inputs or not. Almost paradoxically the "sense of ending" in the Turing Machine as *finite automaton* is based on the (purely theoretical) infinit, endless tape for intermediary notation and symbol storage. Different from the continuous magnetic tape loops in "closed circuit" audio and video art[15], the iterative configurations of a loop in digital computing are radically discontinuous. Iterative and recursive procedures are the predominant *chrono-tropes* in computing time, culminating in the backpropagation of "big data" within artificial neuronal nets in "deep" machine learning.

The Computer as Chronopoet

McLuhan's electricity-focused media theory seems a little bit less outdated when his definition of computing media comes into focus: as a machine whose essential message is rooted in its delicate time mangement. Under this aspect, the computer as the dominant medium of today can not only be understood better, but turns out to be a chronopoet itself, thus actively reshaping current culture on the temporal level. Here is a challenge to "cinematic" spatial perception. "[T]hanks to the computer, visual centralized time is as obsolete as visual space. The Central Processing Unit orchestrates a ballet of operations in simultaneous times, chronology in counterpoint."[16] In this understanding of *actual* computing, when the computational algorithm is implemented in real matter and thus becomes enabled with temporality, it becomes *mousiké* in its ancient Greek sense. Here, McLuhan comes close to the "algorhythmic" indeed (Miyazaki) - carrying his notion of "acoustic space" into the digital kernel.

The computer is not just a "time-based" medium, like performing arts such as theatre and technical media such as cinematography have been before, but becomes itself chrono-poetical. A distinguishing feature of the computer is its (post-) "temporal creativity."[17]

Clock time of digital computing *versus* Bergsonean time

Algorithmic computation is mechanical operations in discrete steps. In order for them to become *effective* computing, a time-discretising clock is required, as instanciated by the weight-driven clock in the Middle Ages with its peculiar media-epistemogenic cybernetic mechanism, the verge escapement. The

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15 See Tilman Baumgärtel, Schleifen. Geschichte und Ästhetik des Loops, Berlin (Kulturverlag Kadmos) 2015

16 Marshall McLuhan / Eric McLuhan 1988: 53, referring to Jeremy Rifkin

17 Marshall McLuhan / Eric McLuhan 1988: 53

accurate automatization of the machine, once developed in Hellenistic Alexandria (Heron's automata) and archaeologically preserved in the Antikythera mechanism of a wheel-driven astronomical calculation device, re-emerged with the escapement-driven clock in the late 13th century, and inversively induced clocked calculation by mechanical automata. What in historiography of technology looks like "resulting" in computational machines like Babbages Analytical Engine[18], in fact is an iterative re-configuration of operational units both in terms of material *techné* and reasoning *lógos*,. In this *ars combinatoria* of inherent rather than simply linear cultural-historical techno-logics, the digital computer is (just) one temporary instanciation.

The neographism of "algorhythmics" (Diss. Miyazaki) not simply derives from a typo or a pun, but from the fusion of programmable medieval Arabic music automata[19] and contemporary Arabic *mathesis* (notably Al Chwarizmi's procedural mathematical calculation with Indian numbers); in another name, the name of the author of the *Liber abaci* and the memory of ancient Greek numerical calculation (arithmetics) fused into the "algorithm". The implementation of a textual listing of source code into a discretely clocked machinery reveals its inherent musicality indeed.

While so-called analogue media are undoubtedly time-based in terms of signal transduction, storage and transfer, and phenomenologocally "unfold to the viewer over time"[20], algorithm-diven media "could be termed time-critical, since not only the duration in the linear sense, but the temporality in the broader sense is part of their 'essence'"[21] - their very existence in discrete states. The temporal processes are not an external parameter to which the artefact is subjected or attributed (by meta-dating), but take place *within* the machine: "[I]f, for example, in writing a code, the different operations can coexist on the same plane, in their implementation in the machine they become a sequence of (discontinuous) signals over time. In digital media every operation must be instantiated at execution time and this time is regulated within the machine itself and is technologically implemented. An example is the integrated circuit 555: it is a timer, or clock, even if this name is improper. It does not measure time, but rather it gives time" (Striano ibid.).

Whereas the ticking clock embodied the rationalist view of mechanical time-thinking (criticized in Heidegger's *Being and Time* in 1927 as "vulgar time"), 20th century mathematical logic "established an algorithmic function, a meta-mathematical axiomatics, abstracted from physical temporalities. With the

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18 See https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019, referring to Bolter 1984

19 See E. Wiedemann / F. Hauser, Uhr des Archimedes und zwei andere Vorrichtungen, Halle (Karras) 1918. On the Mursi brothers, see xxx, in: Zielinski (ed.), Variantology xxx

20 C. Dover, What Is "Time-Based Media"? A Q&A with Guggenheim Conservator Joanna Phillips, in: Checklist: Stories on art, design, conservation, and more shed light on the Guggenheim's past, present, and future, March 4, 2014, https://www.guggenheim.org/blogs/checklist/what-is-time-based-media-a-q-and-a-with-guggenheim-conservator-joanna-phillips, accessed October 25, 2018

21 Striano 2018, conclusion to chap. 2.2 "Time and Temporality"

invention of the Turing Machine, time was not simply disentangled from physical causes, but more importantly, algorithmic functions made time itself both programmable and programmatic. Turing Machines "are above all predictability machines"[22].

With the distinction between formal computation and physical computing, the question arises: "How is formal time embedded in real?"[23], that is: How does the symbolic time regime related to physically defined time?

Interactive, asynchronous and distributive computing in current digital society has opened computational thinking for descriptions beyond closed systems of computability in terms of axioms and deductive rules. With so-called "deep learning", a nonhuman form of computation has emerged from within. With the development of neural nets computations and machine learning AI, "the computational tasks of communicating, sharing, and coordinating data have become governed by asymmetric modes of predictabilities (from the sub-millisecond speeds of algorithmic interactions" in High Frequency Trading "to the distributive processing of clusters computers). Whilst the temporal complexity of computation seems to have accelerated the conflicts between formal and physical time", Luciana Parisi proposes to explore "how the future-oriented automation of thinking implies that abstract time is implicit within physical temporalities", and to rehtink temporality "through and with the temporalities of machines"[24].

In his *Cybernetics* from 1948, Norbert Wiener framed the history of the industrial automaton according to three stages and temporalities: the Newtonian age with its clocks, the industrial age with its thermodynamic engines, and the contemporary world of cybernetic reasoning. According to Wiener, automated techno-mathematics rather exists in the Bergsonian time, just like the living organism, since it is not following the linear and reversible Newtonian time any more. "Wiener took meteorology as example of the statistical science to study the expanding and temperamental character of cybernetics." The computational sphere as well is "producing its own incomputable temporalities, as much unpredictable as the shape of clouds and financial markets" with its "chaotic temporalities of High-Frequency Trading" with its "supersocial machinic intelligence"[25].

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22 From the abstract to: *Automated Temporalities*, workshop hosted by Luciana Parisi, 14 March 2016, in the *Thinking Together* discourse program within the festival MaerzMusik, Berlin, Haus der Berliner Festspiele; 12 / 13 March 2016

23 From the abstract to: *Automated Temporalities*, workshop hosted by Luciana Parisi, 14 March 2016, in the *Thinking Together* discourse program within the festival MaerzMusik, Berlin, Haus der Berliner Festspiele; 12 / 13 March 2016

24 From the abstract to: *Automated Temporalities*, workshop hosted by Luciana Parisi, 14 March 2016, in the *Thinking Together* discourse program within the festival MaerzMusik, Berlin, Haus der Berliner Festspiele; 12 / 13 March 2016

25 Matteo Pasquinelli, The Time of the Automaton: Finance and the Algorithmic Division of Value, lecture at the conference *Time and the Digital Universe* , within the festival MaerzMusik, Berlin, Haus der Berliner Festspiele, Berlin, 12. / 13. March 2016

"Smearing" Time-Discrete Computing

The practice of temporal smearing treats time as shapable, different from the equidistant discrete clock beat - kind of analog time computation. This can be extended to locally adaptive timing, continuous time zone strechting. "Smeared time suggestively evokes the soft clocks of Dali and asks to be narrativized"[26], against non-narrative computation. Digital computers, in their actual technical realisation, are discrete state machines indeed. The conceptual "time smear demonstrates why this is so as it seeks to avoid the abruptness of the digital, the raggedness of leaps, attention-grabbing and alert-triggering irregularities" (ibid.). But even if the concept apparently affirms the supremacy of time-discrete computation, its media message is a different one. "Instead of acceleration as squared velocity over time, time itself becomes a function, a derivative of an acceleration process that needs, in some ways to be thought of as anti-time" (ibid.).

In a shift from the classical clocked framework to adaptive time, the introduction of leap smears within the Google chronosphere is both a confirmation and deconstruction of time-discrete computing. Leap seconds are critical instanciations of kairotic time, "an auspicious micro-moment that is both techno-mathematically pre-defined and decisive for ensuring operationality. Google’s execution of time-critical processes establishes its mastery over the measurement and manipulation of humanly imperceptible micro-temporal events. Measurement is crucial to time-criticality and a leap second can be further divided into smaller units and precisely distributed across the smear. Google reasserts the primacy of the relation between time and number and the enduring legacy of Aristotle for media archaeology, which distances itself from Bergsonian duration in order to embrace techno-mathematical time [...]" (ibid.). The familiar cultural semantics of "time", in human discourse, still lags behind.

SEQUENTIAL LETTERS, OPERATIVE NUMBERS, NON-NARRATIVE TIME. The temporal message of computing media

Computational listings replacing historical narratives

The idea of a progressive historical time, according to Vilém Flusser, is an implication of alphabetic writing which reduced the multidimensionality of objects and images to linear, sequential lines. According to Marshall McLuhan, the invention of the printing press, as mechanised form of alphabetic writing, induced a further escalation, and gave rise not only to perspective in Renaissance painting, but as well "print produced the idea of a past in distant perspective"[27]. Historical consciousness, read this way, is the direct function of

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26 Gary Genosko / Paul Hegarty, Where Has Become of Time? Temporal Smearing and Media Theory, https://semioticon.com/semiotix/2018/03/where-has-become-of-time-temporal-smearing-and-media-theory; accessed 29 June, 2018

27 Marshall McLuhan, The Gutenberg Galaxy. The Making of Typographic Man, Toronto (University of Toronto Press) 1962, 58

specific cultural techniques. But its escalation into media technologies proper subverts the historical sense of time as such.

When events are simply registered (~~historio~~-)graphically with no more dramatic sense of ending, what remains in the end are listings - a reduction of narrative to its essentials, like On Kawara's "date art" paintings. The artistic writing systems of Hanne Darbovens as well turn what used to be narrative historiography into lists (e. g. *Bismarckzeit*, 1978): purely serial writing, corresponding with the computational *histoire sérielle* in the Franch school of historians around the journal *Annales*. Narrative elegance is replaced by mathematical procedures of time series.

The loss of historical consciousness as philosophically transcendent reference for the selection of information in combination with the increasing technological manipulation of the time axis is based on the simple storage of all incoming data, down to the electronic mail accounts on almost every private computer desk. The end of history is the future of the archive, a post-historical condition which does not privilege progressive linearities any more, but calculates in nonlinear discrete states which, in the mathematical theory of communication engineering and in digital computation, is its pre-condition for data processing and transfer.

Game time

In traditional media the relation and distribution of linearity and non-linearity mostly converges with the patterns of narrativity. Narration produces in its classical structure of beginnging, midlee and end, a linearly unfolding sequence which allows for non-linear couplings, differering according to the individual laws of media. While movies represent closed blocks of length, television developed the weekly series and its repetition. With hypertextual media (computer games, and the World Wide Web), non-temporal modes of beginning and end become aquainted: hypertime. The point and moment to step in is almost arbitrary.

Expressed in the mathematical theory of graphs, an adventure-computer game is defined by a beginning and an ending (almost „Homeric narrating“, according to Erich Auerbach): everything which happens between point *a* and point *b* in binary space partitioning.

While human memory remembers the same response to the same signal, a counting function counts it different each time.[28] This is non-narrative time in action, replacing *raconter* (in French) by *conter*, disrupturing narrative (German "Er/zählung"). For the first time, in the so-called digital age historiography does not take place on the symbolical level of the phonetic alphabet exclusively, but on the level of electronically embodied alpha-numerics. In binary form the year 2000, f. e., appears as numerical string „11111010000“, reminding us not to be seduces by narrative suggestion, but to calculate in discrete states, with the consequence not to tell events intransitively but to count them transitively, quantizing data. Media theorist Lev Manovich (in a chapter of his book *The*

28 Spencer-Brown 1994: 65

Language of New Media) calls this the aesthetics of data banks, corresponding with a data-archaeological information ascetitics. Beginning and end, in computing media, are not structured by dramatical structures any more, but by the (equally complex) logic of *count down*.

McLuhan at the borderline of digital computing: *chronopoiesis*

McLuhan's emphasis on the medium message of electricity (its simultaneous "acoustic space") hampered him to conceive the computer otherwise than marginally. In terms of computation, he considered the ancient Greek phonetic alphabet responsible for the supremacy, in occidental culture, of linear, analytic, visually based acquisition of knowledge, resulting in the geometry of control systems.

McLuhan, with his servomechanistic concept of man-machine symbiosis, heavily refers to the cybernetic epistemology of his days, but significantly blinds out its mathematical foundation on which Norbert Wiener always insisted - a mathematization which ultimately replaced McLuhan's vision of a synchronous, instant and resonant "acoustic space" by digital calculation.[29]

McLuhan's *Understanding Media* finishes with a chapter on "automatization", but misses to perceive the computer in terms of the *calculus*. In chapter 11 of *Understanding Media* McLuhan defines the nature of the number as "an extension and separation of our most intimate and interrelating acticity, our sense of touch"[30] - when fingers are used for discrete counting. But computing it more than the numerical mathematization ("digitization") of a machine; after Boole and Hilbert, computing is rather a functiuon of the algorithm: the mechanization of mathematics and logical reasoning.

The essential von-Neumann architecture of current computing as algorithmic and storage-programmable symbolic machine is acknowledged only in the posthumously edited work *Laws of Media*). In the best tradition of the central thesis of *Understanding Media*, McLuhan (both father and son) try to identify the central "message" of the digital computer, less than its impact on individual or social communication which has been dominated by the "Personal Computer" concept and Graphical User Interface since.

McLuhan transforms from a historicised into an up-to-date media theorist when reading his posthumous work. All of a sudden, McLuhan seems a little bit less dead, with his identification that the essential message of computing machinery is rooted in its delicate time mangement. Under this aspect, the programmable discrete computer turns out to be a chrono-poet itself, actively *biasing* (Innis) current culture on the basic or *a priori* (Kant) level which George Kubler once described in his *Shape of Time*. Even though this insight has been borrowed from other scholars, it is directed by McLuhan's remarkable skill to adapt the crucial arguments: "Jeremy Rifkin shows that, thanks to the

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29 See Martina Leeker, Camouflagen des Computers. McLuhan und die Neo-Avantgarden der 1960er Jahre, in: de Kerckhove et al. (eds) 2008: 345-374 (357)

30 McLuhan 1964: 107

computer, visual centralized time is as obsolte as visual space. The Central Processing Unit orchestrates a ballet of operations in simultaneous times, chronology in counterpoint."[31] Even it this description misses the strictly "one bit at a time" essence of data processing, it is an understanding of *mousiké* in its ancient Greek sense. Here, McLuhan comes close to what has recently been termed the "algorhythmic" (Shintaro Miyazaki)[32] - carrying his notion of "acoustic space" into the digital kernel.

Thus the computer is not just time-based as performing arts and technical media before, but itself becomes chrono-poetical. A distinguishing feature of the computer is "its temporal creativity"[33]. Refering to David Bolter's *Turing's Man*[34], McLuhan points out "that while clocks are all set to the same exacting sequence, duration, and rhythm, the computer is free to manipulate all three of these temporal dimensions by merely changing the program"[35] - which is true especially for the von Neumann architecture of computing, a concrete embodiment of the algorithms as being-in-the-world, and thus: in time. "With this new timepiece, time is no longer a single fixed reference point that exists external to events. Time is now 'information' and is choreographed directly into the programs by the central processor" (ibid.); this choreography is media theatre in its dramatic, time-operative sense. Computers trigger the age of "multiple times" (Bolter); every program here has its own unique sequences, durations, ryhthms. "The clock dial is an analogue of the solar day, an acknowledgement that we perceive time revolving in a circle, corresponding to the rotation of the earth. In contrast, computer time is independent of nature: it creates its own context" (ibid.) - up to so-called Internet Time. Genuine media time is *Eigenzeit* just like in acoustic space every event creates its own spatiotemporal field. Indeed, the computer imprints a unique temporality into every program, which makes all the difference between an alorithms written with pencil on paper (like a musical score) and its implementation as an actually running program (like a musical performance differs from its symbolic score). The message of the computer as medium is not just its temporality, but more: its different hard- and software-biased tempo realities. The totalizing cultural and semantic reference "time" implodes. It is the timing mechanism within the computer which brings it close to what Aristoxenos once coined *chronoi* for measuring the temporal duration in music, dance and prosodic speech).[36] Media theory, today, thus needs to be algo-rhythmic itself, just as the conventional concept of media history is being replaced by chrono-archival reconfigurations and media-archaeological recursions.

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31 Marshall McLuhan / Eric McLuhan 1988: 53

32 Shintaro Miyazaki, Das Algo*rhythmische*. Microsounds an der Schwelle zwischen Klang und Rhythmus, in: Axel Volmar (ed), Zeitkritische Medien, Berlin (Kulturverlag Kadmos) 2009, 383-396

33 Marshall McLuhan / Eric McLuhan 1988: 53

34 David Bolter, Turing´s Man. Western Culture in the Computer Age, Chapel Hill (The University of North Carolina Press) 1984, 38 f.

35 McLuhan / McLuhan 1988: 53

36 Aristoxenus, Elementa Rhythmica. The Fragment of Book II and the Additional Evidence for Aristoxenian Rhythmic Theory, ed. Lionel Pearson, Oxford (Clarendon Press) 1990

Time-discrete micro-temporality

The analytic focus on discrete micro-temporality within and inbetween the ICs of microprocessors identifies data storage and processing as an active process, not simply as archival *stasis*. Already the electronic image from analog video tape had to be continuously refreshed, just like the line and frame update frequency in digital imaging. Only due to physiologically slow human perception it appears as a stable image - which makes all the difference between media archaeology and phenomenology. The turingmachine itself is a step-wise, time-discrete reconfiguration of machine states, but in its technological escalations the motion and dynamics of the hard drive became ultraspeed. The micro-infrastructures of "digital memory" in the von-Neumann architecture of computing can not be reduced to its Read Only Memory chips but requires constant regeneration from Random Access Memory technologies from the early ultra-sonic mercury delay lines, the Williams tube, and rotating magnetic cylinders onwards.

Concerning the essentially binary operations of numerical computing which extend to "big data" processing in the Digital Humanities, translating every "wordly" physical signals into voltages which count as numbers (the essential effect of A / D conversion in the sample-and-hold mechanis) results in an ahistorical short circuit between the digital present and the ancient Pythagorean mathematical world order, kind of Moebius looped resursion. While this is apparent on the level of the symbolical order, the difference is in its physical implementations (and resulting frictions[37]), Here, taking into account time-criticality and micro-temporality of data-processing matter makes all the difference that defines the algorithmicized present.

Time-criticality of computing and computing (with) time

According to Martin Heidegger's *Sein und Zeit* (1927), it is the awareness of death which inscribes a temporal vector into the human sense of being, as a phenomenologically deferred *futurum exactum*. This pattern escalates dramatically within electronic media, turning Heidegger's question from an ontological one into an analysis of micro-temporalities which take place there, critically. The mechanical clock already, with its mechanical "escapement", literally has a sense of the vantage point (the flight) of time. Heidegger's ontological archaeology of temporality within human being stays decisively anthropocentric, explicitely opposed to reified time as embodied in a trivial machine: the mechanical clock. But with the cultural mastering of electro-magnetism (electronics) a form of processing temporal moments came into the world which unfolds a temporal *kosmos* of its own, its very own chronosphere which needs (analogous to Heidegger's analysis) an analysis of its media-*arché* which does no derive origins but re-veals groundings, uncovering the eventuality, which is: temporality and finiteness of being. Media archaeology

37 As discussed in Morton Riis, Machine Music. A Media Archaeological Excavation, Aarhus 2012; PhD dissertation at The Royal Academy of Music, Aarhus Department of Aesthetics and Communication, Aarhus University, 72 f.

performs this time-critically, on the micro-temporal level of electrophysical media.

In mathematics, Newton and Leibniz have developed a mighty tool known now as differential and integral calculation in order to cope - for the first time in occidental intellectual history - with temporal objects, notably speed and acceleration. Analogue computing has such a sense of physical time, different from numerical computing. Numerical mathematics rather constructs discrete algorithms to cope with continual mathematical problems in two ways: direct computing which after a finite temporal process delivers the exact solution, and approximation. Digital clocks in the technical sense do not drive indented wheels any more, but count by numbers. It was Aristotle, who in book IV of his *Physics* has defined time as a function of numerical measuring a movement. Heidegger opposed „vulgar“ mechanical time - as objectified in the ticking clock - by „essential“ time.[38] Countable time is a form of periodic measuring.

What separates the actual electronic computer from the Turing model as a literal "paper machine" is its implementation into not just symbolic, but physical operativity, that is: the speed of electron(ic)s. According to Moore's Law, not only the density but as well the speed of semiconductors in micro-chips doubles more or less every 18 month.

[Digital computing, basically consisting of a set of switching components, has its own sense of ending: "[T]he growth rate of possible interconnections between these elements, that is, of the computing power as such, has proven to have as its upper bound a square root function"[39], since it can not "keep up with polynomial growth rates in problem size"[40]. There are complexities which can only be dealt with in polynomial time by non-deterministic machines.[41] The isolation between discrete electronic elements techno-logically "accounts for a drawback in connectivity that otherwise, 'according to current force laws' as well as to te basics of combinatorial logics, would be bounded only by a maximum equalling the square number of all elements involved."[42] Thermal Boltzmann-entropy here returns from within the symbolical regime of informational Shannon-entropy.]

The temporal *punctum* becomes decisive in electronic computing: "The *interval* is where the action *is*"[43]; unwillingly, McLuhan here graps the essence of binary data processing - the temporal gap in switching between Zero and One. It was the god-father of cybernetics Norbert Wiener who - remarkably within the discussion of analog *versus* digital computing during the New York "Macy conferences" coined the term "time of non-reality" for the switching time between zero and one.[44] The way digital computers *draw a distinction* (alluding

38 Heidegger 1927, § 81
39 Kittler, There is No Software, 1992: 89
40 Conrad, in: Herken (ed.) 1988: 293
41 See Michael R. Garey / David S. Johnson, Computers and Intractability. A Guide to the Theory of NP-Completeness, San Francisco (Freeman) 1979
42 Kittler 1992: 89, referring to Conrad 1992: 290
43 Marshall McLuhan, Letter to Barbara Ward, 9 February, 1973, in: Letters of Marshall McLuhan, selected and edited by Matie Molinaro / Corinne McLuhan / William Toye, Toronto / Oxford / New York (Oxford University Press) 1987, 466
44 See Claus Pias (ed.), Cybernetics - Kybernetik. The Macy Conferences 1946-1953, vol. 1: Transactions / Protokolle, Zürich / Berlin (diaphanes) 2003,

to Spencer-Brown) itself is not simply a logical discrimination but takes a micro-temporal switching within flip-flop circuits. Like the signifier in structural linguistics (de Saussure's phonemes) is nothing by its own and is defined only by its differential oppositions, the difference is not geometrical, but a *différance* in Derrida's sense, that is: an act of temporal deferment. Even if this moment ideally tends towards the Dirac impulse (a *punctum* with ultimate amplitude but no temporal extension), it will always - once the logic design is implemented into physical matter - take its temporal delay *delta-t* which is time-critical when it comes to computing time. Different from pure mathematical symbol notation on paper, techno-mathematicality is physically operative, that is: within the time-critical regime.

It is significantly in a publication entitled *Faster than Thought* that the reason for the success of early vacuum-tubes based computers over electro-mechanical machines is being explained: "All the operations [...] carried out by these valves could equally well be achieved by the use of ordinary switches and variable resistances, but for one thing - time. Valves can be switched on and off almost instantaneously."[45] Still, any logical or numerical switching of discrete information consume a minimal interval of time with which it literally has to count. Even quantum mechanics implies the discrete behaviour of physical nature in regard to available energies and time; the switching of a single quantum information bit requires a minimum amount of time. According to the Margolus-Levitin theorem, switching time is inversely proportional to the energy expended.[46] At that moment, "time" emancipates from all metaphysical transcendence and is treated as an operator. Functional timing, not "time" is subject and object of media tempor(e)ality.

Algor(h)ithmic computing and its "musicality"

At each given moment of calculation, the turingmachine is an operative function (Turing 1937) of its "inner state" defined by its instruction and transition tables. But in its realization as techno-logical computer, this mechanism is discretely "clocked" as well, which is frequently overlooked. The algorithm becomes "algorhythmic" (Miyazaki) at that moment.

Rhythmic musical automata from the Arabic Medieval Age and musical composition machines such as designed by Athanasius Kircher in the 1660s are direct predecessors of algorithmic computer music(ality). Such machines relied on automated processes that systemised the musical content and performance practices. The programmability of the cylinders and the programmability of modern computers are related to the regular revolutions of the pinned musical barrels and the constant clock frequency in modern CPUs.

[For a "musical" demonstration of a computer hard drive's dynamic temporality see *Harddisko* (2004) by Valentina Vuksic; the pieces *Analog HD1* (2011) and

158 f.

45 B. V. Bowden (ed.), Faster Than Thought. A Symposium on Digital Computing Machines, London (Pitman Publishing) 1953; here quoted from the paperback edition 1971, 42

46 See Seth Lloyd, Computational capacity of the universe, in: Physical Review Letters, vol. 88 (2002)

Analog HD2 (2012) by Gijs Gieskes conceptualise the hard drive's physicality.]

Code studies can not be reduced to its focus on the symbolic order. Critical media philology attends to its techno-logical implementation as software performance. This attendance can be achieved by breaking the purely computational logic, switching to the concept of implicit sonicity which takes computational tempor(e)ality into account. While superimposed thermic and acoustic oscillations have become mathematically calculable with Fourier Analysis, in reverse, the inherent sonicity of temporalized mathematics in computing technology is made phenomeno-logically accessible *via* the ear, the human time organ. By sonifying data processing in computer architectures, humans can literally "understand" digital media, listening to the rhythms of algorithms and thereby accessing the microtemporalities of cycling units. Such listening with media archaeological ears does not refer to music as cultural content, but to the implicitely sonic dimension of computational action.

A machine operating in discrete steps is always something more than a symbolic configuration, just like an actual sounding instrument differs from its symbolic prescription by a musical score. That is why algorithmic thought can not be understood exclusively in terms of abstract computation, but as embodied cognition, which only unfolds in actual computing, algorythmically.

An alert in data streams can better be addressed to time-critical ears (as practiced in earthquake monitoring) than to visual attention[47]. Different from the ocularcentristic paradigm of "computers as theatre" (Brenda Laurel), that is: the visual Interface, computers can rather be modelled as a concert hall with its orchestra, up-dating McLuhan's notion of "acoustic space" to the digital regime.

[The curator of the department *Computing and Control* at the National Museum of Science and Industry in London, Doron Swade, once described the museological challange of software: While it is still a cultural artefact, it is no material object any more, since it unfolds only in computing, that is: "algorythmically"[48]. Software belongs to the "generic objects (media)"[49]. A computer which only passively is on museum display is not in any "medium" state. It therefore requires a display of its time-and bit-critical data processing. One way to make such processuality perceivable to human cognition is sonifying data processing into acoustic frequencies which can thereby be literally „understood“ by the human ear - a sonic computer museology. Software, like an ancient piano score instruction, "can be executed by a human pianist as well as on a player piano"[50].]

The sono-analytic, "acoustemic"[51] approach allows to (literally) "understand" processual algorithmics.

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47 See, e. g., the visual data metaphor in Asymptote's design for a virtual *New York Stock Exchange*

48 See Shintaro Miyazaki, xxx

49 Doron Swade, Collecting Software: Preserving Information in an Object-Centred Culture, in: History and Computing, vol. 4, no. 3 (1992), 206-210 (208)

50 Cramer 2002

51 See xxx

THE COMPUTATIONAL MACHINE

The Limits of Computability vs. Effective Computing

The metamathematical discussion of the incomputable, and the limits of algorithmic analysis, has resulted in a theoretical mechanism of computation, known as *turingmachine*.[52] Turing's paper from 1937 has been preceeded by Kurt Gödel's *incompleteness theorems* in 1931: In any sufficiently powerful logical system statements can be formulated which can neither be proved nor disproved within the system. *Ex negativo*, even unpredictability thereby remains *within* the symbolic regime of logical reasoning. The turingmachine which conceptually resulted from a negative answer to the limits of algorithmic computation and challenges such as the *Entscheidungs-* and the *Halteproblem*, almost (t)autologically limits itself to the galaxy of computable numbers.

While the turingmachine theoretically, and in terms of "software", originated from efforts to formalise the *limits* of numerical computation (which, in a temporal sense, coincides with the *Halteproblem*), it practically resulted in an even more hardware-oriented techno-logical reasoning: computing.

Time-sharing: *Understanding Media* in the age of Internet

In order to understand media in the age of the Internet, the focus on its time-critical aspects turns out an essential message of Internet-based communication (especially in the form of so-called Web 2.0).

McLuhan is not just a historical hero of media theories. Even in times of the Internet and mobile media, it is still useful to follow his advice not to ask about the content and its social implications only but to look equally at the subliminal message or rather massage which is thereby being induced.

McLuhan analysed the cultural impact of media not on the level of semantic content like communication studies, but rather directed attention to their *sublime*, non-figurative message (in the sense of Immanuel Kant and Edward Burke), that is: the ways media act upon and reshape the perceptional schemata within humans. As such, media power operates by "amplifying human sensory preceptors"[53] in their different physiological channels. Among these, the amplification of temporal schemata reigns supreme. But this amplification leads to irritations. Walter Benjamin in his 1936 essay on the work of art in the age of technical reproduction insisted that aesthetic "aura" depends on real presence in space and time. Nervertheless, electronic

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52 M. Beatrice Fazi, Contingent Computation: Abstraction, Experience, and Indeterminacy in Computational Aesthetics, London (Rowman & Littlefield) 2018

53 Robert Babe, McLuhan and the Electronic Archives, in: Old Messengers, New Media. The Legacy of Innis and McLuhan, Essays: Archives as Medium, *online* http://www.collectionscanada.gc.ca/innis-mcluhan/002033-4010-e.html, accessed April 29, 2009

television by means of *live* transmission is able to generate an impression of presence by real signal synchronicity in time across spatial distance. At the same time, human senses have difficulties to differentiate *live* from broadcasting of *live from tape* or (nowadays) digital transmission in *real time*: "One can no longer distinguish, visually or aurally, between that which is reproduced and its reproduction [...] not even discern *that* or *when* reproduction or repetition, in the manifest sense of recording or replaying, is taking place. We must be informed whether or not what we are seeing is 'live'."[54]

The liveness of media springs from their temporal effects. In a McLuhanite reading, the essential message of electronic communication transfer is in its temporal field. The previous technical media of storing physical events (photography, phonography, cinematography) have been counter-balanced by media of pure transfer in the 20th century. Prominently ranging among these has been radio based on the electronic vacuum tube and its functional successor (though irreplacable in the case of the TV monitor tube), the transistor. The thermionic tube has been the defining element of electronics as such. McLuhan neglected this decisive media-archaeological artefact, remaining a philologist rather than an engineer, thus being media scholar only half way. That is how he can write of "electricity" as the paradigmatic energy form of the present, whereas electronics does not simply mean electric energy but the directability, almost governance (both analogue and logical) of free-floating electrons in vacuum space with almost light speed, thus allowing for low-currency based information engineering.

The characteristic of early radio has been that it broadcasted music and speech radically "live", without storing the signals at all. From that derives a general phenomenologic insight: Analog mass media like radio and television exist always only momentarily in the "now", being located in time itself. In (and for) the temporal sense, radio is a "hot" medium. McLuhan's differentiation between "hot" and "cold" media can be applied to the technical modes of generating temporal affects indeed, ranging between intensive and extensive temporal involvement of the participant. The "live" effect of technical communication takes place since the age of the telephone (whereas telegraphy, intermediated by the inscription paper of dashes and dots, rather represented what we now call differential "live on tape".

Such a time-critically sharpened reading of McLuhan's medium / message theorem leads to new ways of approaching the temporal bias of technical media which is not only a macro-temporal *bias of communication* in a Harold Innis-mode of media theory, "but an intensive microtemporality."[55]

In a very different way, the temporal message of digital communication media is in temporal deferal: from *live on tape* to media content *on demand*. This is the temporal signature of webcasting.[56] This time-critical souvereignty and immediacy in access means a "tactilization" of what has been non-individual

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54 Samuel Weber, Mass Mediauras. Form, Technics, Media, Stanford (Stanford UP) 1996, 121

55 Jussi Parikka, Operative Media Archaeology. Wolfgang Ernst's Materialist Media Diagrammatics, in: Theory Culture & Society, xxx

mass media broadcasting before, in fact: an almost *haptic* access to media time (to use one of McLuhan's terms. Something disappears at the same time: the clear distinction between what is present and what is past, what is transmitted "live" and what comes out of the archive. Some online-services of radio or TV channels offer access to commentaries on current news, while at the same time offering access to other commentaries on previous occasions. The delineations of the archive to the present become diffuse, almost fuzzy.

Technical *Eigenzeit* (the temporal logic inherent to media) shapes the collective sense of time. This is the message of Internet-based communication: The dominant communication platform of today, the World Wide Web, needs to be analysed on its operative level of temporal processualities and eventalities.

Communication networks are not just topological systems being expressed by hypertextual links, but as well time-critical processes. A symptom of this is a The answer to this is a term which does not nominate a new medium but declares the temporal mode its decisive media-theoretical criterium: the *real-time web* which is "a set of technologies and practices which enable users to receive information as soon as it is published [...], rather than requiring that they or their software check a source periodically for updates."[57] The communicative practice of *instant messaging* belongs to this temporal field; im McLuhan's sense the message of the medium here is immediacy serving to create the illusion of a pseudo-copresence. This recent form of web economy is being defined by communication within the time-critical realm; cyberspace as *docuverse* is being replaced by an extremely accelerated information processing in cybertime.[58] The Internet thus turns out not to be just a topological extension of a generalized archive, but equally as a chrono-technical "compression of time" (ibid.). This requires a close look at time-critical operations on the physical and logistical level of the Internet, f. e. the "Ping" signal. In the Internet, each data packet into which a document has been sliced is being observed individually; its transfer happens independent from its preceeding or successive packages. This procedure is radically time-critical since is takes place within the so-called Time To Live-field which defines the maximal temporal duration in seconds an IP packet is allowed to exist in the Internet. A counter is progressively being reduced during this routing; in case the TTL-counter reaches zero before the packet has reached its destination, it is being annihilated.[59] Media time is not endless.

Communication, in this sense, is about time-sharing (not primarily about exchange of meaning) - just like in physics, engineerng and systems theory

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56 Andreas Bade, Radio im Internet. Zwei Wege für die "Stimme" im Netz, in: same author, Das Internet als programmbegleitendes Medium des Hörfunks. Historische Entwicklung von Internet, Radio und ihrer Medientheorien, Hamburg (Diplomica Verlag) 2009, 57-86, http://www.mediaculture-online.de

57 http://en.wikipedia.org/wiki/Real-time_web, accessed January 20, 2010

58 "Früher ging es um die Schaffung von Räumen [...], heute geht es um die Zeit selbst, um Chronos, um die Kunst der *longue durée*": Geert Lovink, Was uns wirklich krank macht, in: Frankfurter Allgemeine Zeitung No 140, 21st June 2010, 27 (referring to the media theory of Franco Bernardi)

59 Othmar Kyas, Internet: Zugang, Utilities, Nutzung, Bergheim (DATACOM) 1994, 65

"communication" is about signal interaction first. This reminds of a primary scene in media archaeology, the *momentum* of telegraphy, when one of the first messages exchanged on the Morse system in the United States between Baltimore and Washington was a quest for time - with the response indicating local time in almost immediate speed, (almost) without delay.[60] The message of telegraphy in its early, that is: media-archaological phase, is (about) tempor(e)alities - coupling (synchronizing) sender and reveiver in the time domain which is, in McLuhan's sense, the tactile temporal affect. What has still been verbal time-communication between human operators on the telegrapic channel, later became the technical time signal, with the temporal signal as low frequency modulation of a high frequency signal itself being the message and not *allegorically* carrying another meaning.

The temporal *punctum* becomes decisive: "The *interval* is where the action *is*"[61]; un willingly, McLuhan here graps the essence of binary data processing - the "time of non-reality" (as defined by Norbert Wiener) in switching between Zero and One.

In this aspect, McLuhan at first sight mis-interpreted electronics once more: by understanding the computer as a mere extension of electronics. The point is that the computer conceptually is not dependent on electricity at all but basically a trans-machinic medium, a "paper machine" (in terms Alan Turing). But *computing culture* as it actually became an autopoietic technological system itself (both the individual computer and its interconnections called Internet) is time-critically bound to electric speed indeed.

"Of Other Spaces": Topo-logical Graphs Replacing the Kantean *a priori*

Media archaeological analysis of networks goes down to the hardware (fiber optical cables), Internet traffic protocols (Alexander Galloway) and the source codes ruling digital communication. For a "close" analytic reading of technological ensembles, its wiring, transmission and storage, is accepted to enact an agency of their own, even if their existence is not completely detached from historical, biographical, ecnomical and social contexts.[62] But there are are sub-"social" forces with*in* (or as a *parergon* of) technological formations.

The mathematical theory of information has transformed both the scientific understanding and engineering of human communication, and cultural artefacts. This media-epistemic shift has already created new cognitive territories - in theory. In practice, cultural discourse semantically lags behind the state in which digital technologies already are and act. Digital information

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60 The topic of Florian Sprenger's talk "'Intellect hath conquered time' - The Presence of Electricity and the Rise of Telegraphy" at the conference *Global Communication Electric. Social, Cultural, and Political Aspects of Telegraphy*, 18/19 February 2001, Museum of Communication, Berlin

61 McLuhan, op. cit.

62 Introduction (on "Critical Code Studies") to: Ian Bogost et al., 10 PRINT CHR$(205.5+RND(1)); : GOTO 10, Cambridge, Mass. / London (The MIT Press) 2013, 6

has not yet changed cultural conventions of how humans conceive and inhabit space and time, nor the predominant discourse of history itself, while practically resulting in new, multiple kinds of tempor(e)alities already. Technological chronopoietics involves alternative modes of dealing with what occidental discourse used to call history - if not denying "time" as such.

As has been predicted by Michel Foucault, the present epoch is, above all, the epoch of space and simultaneity as its contemporary condition: "[w]e are in the epoch of juxtaposition, the epoch of the near and far, of the side-by-side, of the dispersed. We are at a moment [...] when our experience of the world is less that of a long life developing through time than that of a network that connects points [...]. The site is defined by relations of proximity between points or elements; formally, we can describe these relations as series, trees, or grids."[63] This formulation of cultural communication is not the prose of humanities any more but mathematical topology - the real language of *archéologie de savoir*.[64] Foucault identifies the importance of the site in a precise media-archaeologtical micro-analysis of *operational* space, of states in transition (aka turingmachine): "the storage of data or of the intermediate results of a calculation in the memory of a machine, the circulation of discrete elements with a random output (automobile traffic is a simple case, or indeed the sounds on a telephone line); the identification of marked or coded elements inside a set that may be randomly distributed, or may be arranged according to single or to multiple classifications." Time itself is a transcendent signifier no more: "Time probably appears to us only as one of the various distributive operations that are possible for the elements that are spread out in space."[65]

Urban architectures can be reformulated as "the set of relations that define the sites of transportation, streets, trains".

[As a spatiotemporal object, a train itself "is an extraordinary bundle of relations because it is something through which one goes, it is also something by means of which one can go from one point to another, and then it is also something that goes by)" (Foucault ibid.).]

Once the outdated Kantean *a priori* of the "spatial" is replaced by the "topological" (nodes, links, net), it is not spatial any more, but a mathematical graph. Thereby, "urban" metaphors fail.

Obscuring media technologies: Online communication, "cloud computing", and the Media Archaeological Response

The emergent effects of "ubiquitous" computing seem to challenge the original *a priori* focus of media analysis on single computer platforms and source code.

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63 Michel Foucault, Of Other Spaces: Utopias and Heterotopias, translated by Jay Miskowiec from the French version ("Des Espace Autres", published in: Architecture / Mouvement / Continuité, October 1984), in: Diacritics, Spring 1986, 22-26; quoted here from the online version http://web.mit.edu/allanmc/www/foucault1.pdf, accessed 12 February, 2019

64 See Kusch 1989

65 Foucault 1986 / 2019

But different from communication studies, material media studies still insist on the technological artefact at the centre of epistemological analysis. In so-called social media, the "social" in fact has become a function of nonhuman communication engineering. Even "cloud computing" still requires a close analysis of its underlying hard- and software, such as a reminder of the giant water cooling systems for hot data processing at the Google data centres in the European North.[66] In order not to let terms like "network" slip into pure metaphors, an analysis of its technical and logical infrastructure (which is optical fiber cables and protocols) needs to be as exact as the description of the electronic flip-flop circuitry which is - alternative embodiments of "unconventional computing" set aside - still the very condition for "binary" computing and artificial neuronal nets. It is not by coincidence, but by epistemological necessity, that Charles S. Peirce, who defined all kinds of deductive logical reasoning as "diagrammatic", has designed the first electric circuit, as operative, techno-logical diagram. "One would then have an electrical analytical engine."[67]

Against precise analysis close to the infrastructural data logistics[68], metaphors like the data "cloud" are literally obscuring, "cloudy" in both the thermodynamic and informational sense of entropy. The current fashion of so-called media ecology puts a veil on the actual technological condition. Only a renewed technological enlightenment will - less allegorically - read the operative diagram of current information society, like it used to open the black box of individual technologies so far. The protocols of Internet traffic are still there to be deciphered with media philological competence in its most ancient sense of *logos*, that is: alpha-numerically.

Where the time-stamp makes the difference: "bitcoin"-based crypto-currency

What has been chronology and annalistic registering of events in the Middle Ages as cultural chrono-technique, has become radically techno-mathematical chrono-logics in contemporary algorithmicized culture. Concepts in digitized economy like the "bitcoin" transform the very notion of "currency" itself. Media archaeological analysis aims at uncovering its nondiscursive infrastructure, its subsemantic stratum, its techno-archival source code in the literal sense.

Essentially, "a bitcoin is nothing more than an easily creatable set of alphanumeric characters" (Nielsen), defined as an electronic chain of digital signatures. Media archaeology analyses not what the bitcoin system is, but what it does. Its core is the timestamp server which "works by taking a hash of a block of items to be timestamped and widely publishing the hash, such as in

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66 Jennifer Holt / Patrick Vonderau, "Where the Internet Lives": Data Centers as Cloud Infrastructure, in: Parks / Starosielki (eds.) 2015: 71-93

67 Alice R. Burks / Arthur W. Burks, The First Electronic Computer. The Atanasoff Story, Ann Arbor (University of Michigan Press) 1989: 347, referring to Peirce's circuit diagram for both switching and memory

68 As argued in Shannon Mattern, Deep Time of Media Infrastructure, in: Parks / Starosielki (ed.) 2015: 71-93 - even if the author traps into the metaphors of the archaeological "excavation"

a newspaper or Usenet post. The timestamp proves that the data must have existed at the time, obviously, in order to get into the hash. Each timestamp includes the previous timestamp in its hash, forming a chain, with each additional timestamp reinforcing the ones before it."[69]

In order to achieve electronic cash transactions without going through a third party such as a financial institution, "[t]he network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work."[70]

[The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers."[71]]

The concept of culculation within finite time returns: "Transactions that are computationally impractical to reverse would protect sellers from fraud [...] using a peer-to-peer distributed timestamp server to generate computational proof of the chronological order of transactions. The system is secure as long as honest nodes collectively control more CPU power than any cooperating group of attacker nodes." (ibid., "Introduction"). There is a new techno-historicism arising: When the coin is simply a chain of previos owners' signatures, "[i]n essence,the coin is never anything more than the history of its ownes. Its entire history of exchange is readable through this system. [...] if a malicious network tries to change the chain of blocks, they would have to redo all the proof of works, and the current one, in the [...] timeframe which becomes more and more unlikely, as the required computational power rises exponentially"[72]. A time-critical task: "The race between the honest chain and an attacker chain can be characterized as a Binomial Random Walk."[73]

[Nakamoto first provides the mathematical formula for probability computation, and later converts it to explicit C code. Nakamoto concludes (chap. 12): "we proposed a peer-to-peer network using proof-of-work to record a public history of transactions that quickly becomes computationally impractical for an attacker to change if honest nodes control a majority of CPU power. The network is robust in its unstructured simplicity. Nodes work all at once with little coordination."]

Bitcoin transactions are publically announced to a network of computers that collect these transactions into a "digital ledger" (Nielsen), which Nakamoto calls a "block" - the new archival register. This archive is not a secret one as soon as the "black box" is opened by examining its algorithmic principles.

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69 Nakamoto 2008: chap. 3 "Timestamp Server"

70 As expressed in the "abstract" to his seminal paper "Bitcoin: A Peer-to-peer Electronic Cash System", (pseudonym) Satashi Nakamoto

71 https://bitcoin.org/bitcoin.pdf, accessed January 24, 2019

72 Allan Gunnar Nielsen, Changing Currencies: The Emerging Cryptocurrency Movement, paper written for the Media Studies Master curriculum *Media Theory and Media Archaeology*, Humboldt University Berlin, May 12, 2018

73 Nakamoto 2008: chap. 11 "Calculations"

Computing "Big Data": Statistics, Archaeology, and the Socio-*lógos*

Algorithmicized sociology originated from predictive statistics. "Will we become the atoms in the 'social physics', first dreamed by the founder sociology Auguste Comte in the middle of 19th century?", Lev Manovich asks in his presentation of an algorithmic tool to compare facial expressions in "selfies" collected from locative media such as Instagram in order to detect the distinct "visual signature" of individual cities.[74] In 1890, Gabriele Tarde declared: "Il est le plus propre à éclairer les faits sociaux par leur côté régulier, mesurable et nombrable"; and "il s'ensuit que la statistique sociologique decrait s'y placer", by „enregistrements stériles", in fact by employing "la méthode graphique de M. Marey ou l'observation des maladies par le myographe, le sphymographe, le pneumographe, sortes de statisticiens mécaniques des contractions, des mouvements respiratoires."[75] In *Le Mouvement* (1894), Marey calls the graphical curves "the language of the phenomena themselves"[76]; by analogy, Tarde defines "les études archéologiques et les études statistiques". Statistians, like the archaeologist, "jette sur les faits humains un regard tout abstrait et impersonnel"[77] - kind of posthumanistic archaeology *avant la lettre*.

With the shift of emphasis in Machine Learning from the algorithmic to the statistical approach, where multi-level backpropagation is self-processing "big data" into results which then only retrospectively can be formalized into an algorithm, the approach becomes more "archaeological" in Tarde's sense indeed.

While "big data" analytics in the nineteenth-century statistical approach, which has been still "archival" in its accumulation of data, already replaced the search for certainties and truths by probabilities, high frequency algorithmics flips to Markov process-based stochastics. Next to such statistical and logic operation, the "historicizing" approach of analysing the present, on the techno-logical side, culminates in pre-emptive computing of the "future in the past" by the anti-aircraft predictors alternatively proposed by Wiener and Shannon in World War Two[78] where, what is nowadays advertised as the "two second advantage" of financial or social knowledge, has been a question of life and death. Predictive and pre-emptive "big data"-based computational analytics detects patterns and trends at the very moment of their *status nascendi*. As advertised by Spotfire in the tradition of hermeneutic reading, "emerging trends and patterns hidden in vast quantities of multivariant data" can be spotted by AI neuronal nets even when they are not yet perceivable for human cognition,

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74 Electronic communication by Lev Manovich, May 2014; see www.selfiecity.net

75 Tarde 1890: 122 f.

76 Quoted after Giedion 1982: 40

77 Gabriel Tarde, Les lois de l´imitation, Paris 1890, chap. IV (Qu´est-ce que l'histoire?), section "L'Archéologie et la Statistique", 99 and 114

78 See Axel Roch / Bernhard Siegert, Maschinen, die Maschinen verfolgen. Über Claude E. Shannons und Norbert Wieners Flugabwehrsysteme, in: Sigrid Schade / Georg Christoph Tholen (Hg.), Konfigurationen. Zwischen Kunst und Medien, München (Fink) 2003, 219-230

anticipating opportunities and risks "by seamlessly integrating predictive models and real-time event streams to deliver the Two-Second Advantage"[79].

"A study of emergent collective effects and spontaneous computations must necessarily focus on the nonlinearity of the input-output relationship. The essence of computation is nonlinear logical operations. The particle interactions that produce true collective effects in particle dynamics come from a nonlinear dependence of forces on positions of the particles."[80] The phenomenon of "emergent" knowledge from big data-fed machine learning can be compared to collective patterns of behaviour in human society only in its statistical, computable sense. Radical media archaeology, material hermeneutics and digital forensics care about "social" implications of technology rather in its micro-connective sense.

Bruno Latour's Actor-Network Theory has liberated the "social" from its limited anthropocentric sense; still, such extended usage of the term "social" carrying with it the metaphorical ghost of a human-like collective. Different from Actor-Network Theory, media archaeology keeps both regimes analytically apart; it rather replaces "society" by cybernetic systems theory. André-Marie Ampère, in his *Tableaux synoptiques des sciences et des arts* (3rd Tableau), associated the *critique archéologique* with *statistique* (social economy) and *cybernetique* (gouvernment).[81]

Still, even ANT does not explain techno-logics, as long as it interprets technologies as part of the "texture" of society (as expressed in Latour's *Pandora's box*). The Heideggerean *Ge-stell*, becoming technically operative in programmable devices like the Jacquard loom, is a rule-governed enframing, but no society. Media archaeological analysis radically shifts the perspective from outside (intransitive) to "from within" technologies, in order to make their operative enunciations media-theoretically explicit.

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79 As quoted from a Tibco® event in London, 2013, in the "Introduction" to Amoore / Piotukh (eds.) 2016

80 J. J. Hopfield, Neuronal networks and physical sytsems with emergent collective computational abilities, in: Proceedings of the National Academy of Sciences of the United States of America, vol. 79 (April 1982), 2554-2558 (2555)

81 Essai sur la philosophie des sciences, ou: Exposition anlytique d´une classification naturelle de toutes les connaissances humaines, preface (xvii)