[Wolfgang Ernst: SCRIPTS ON TECHNICAL MEDIA]

TEXT BLOCK "THE LOGO-TECHNICAL MECHANISM (ANALOG AND TIME-DISCRETE COMPUTING)"

[unpublished so far, roughly edited]

Detailled content by chapters:

- Digital computing from analog embedding
- (Non-)Computable "Emergence"

THERE IS NO "DEAD MEDIUM". On the Actuality of Analog Computing in Times of Ubiquitous Digital Computation

a) Analog Computing as Alternative Mathematics:
- The Renaissance of Analog Computing
- The media-epistemological core dichotomy: physical *computing* vs. mathematical *computation*
- The Future of Analog Computing

b) Remembering "Exact Aesthetics":
- Analog Computing, and the Art / Science Gap
- "Generative Art": a Byproduct of Science?
- Oscillographic "Rhyhtmograms" vs. Digital Algorithm
- ["Visual music"? The Implicit Sonicity of Analog Computing]
- Media-Active Archaeology: Continuing the Machine
- Doing Chaos: Pseudo- *versus* True Random

c) Analog Computing on / as Film:
- Rekveld's Media Archaeology of Analog Computing, and the Cold War Context
- Joost Rekveld's Dialogue with the Analog Machine
- Analog Computing Itself in Being vs. Recording of its audio-visual Phenomena

DOES COMPUTATION HAVE A SENSE OF ENDING?
- Algorithmic "being-to-death": the *Halteproblem* of Finite State Machines
- TempoR(e)alities in computation
- Computing (with) time: clocked computational *timing*
- "Timed" Symbols: The Reconfigurable (Turing) Machine
- "Interrupt"
- The Computer as Chronopoet
- Clock time of digital computing *versus* Bergsonean time
- "Smearing" Time-Discrete Computing

SEQUENTIAL LETTERS, OPERATIVE NUMBERS, NON-NARRATIVE TIME. The Temporal Message of Computing Media
- Computational listings replacing historical narratives
- Game time
- McLuhan at the borderline of digital computing: *chronopoiesis*
- Time-discrete micro-temporality
- Time-criticality of computing and computing (with) time
- Should there be a Media Ecology of Computation?
- Algor(h)ithmic Computing and its "Musicality"
- Towards a Computational Epistemology of Media Tempor(e)alities

THE COMPUTATIONAL (TIME) MACHINE
- Time-sharing: *Understanding Media* in the age of Internet
- "Of Other Spaces": Topo-logical Graphs Replacing the Kantean *a priori*
- Obscuring Media Technologies: Online communication, "cloud computing", and the Media Archaeological Response
- Where the time-stamp makes the difference: "bitcoin"-based crypto-currency
- Computing "Big Data": Statistics, Archaeology, and the Socio-*Lógos*

==========

Digital computing from analog embedding

With digital computers, actually two types of machines exist: still "analog" electronics, since "the organs that we call digital are, in reality, continuous"[1], but their behaviour is discrete in its mathematical mechanism a.k.a. algorithms (the "Turing machine").

"[...] real-world agents have a number of properties that most virtual agents do not"[2], therefore demanding for a more adaptive, "morphological" (ibid.), "unconventional" (Adamatzky) or even "irrational" computing (media artist Ralf Baecker's 2011 installation[3]).

A US company for electronic health care and security technology products is named ANALOGIC. One of its counting devices displays discrete numbers as a function of a fully analogue circuit in von Neumann's sense.

Instead of another variance of electronic technologies, the digital computer has been a machine born from mathematical reasoning, not

---

1 John von Neumann, in: Gerard 1950: 177
2 Rolf Pfeifer / Josh Bongard, How the Body Shapes the Way We Think. A New View of Intelligence, Cambridge, Mass. / London (MIT Press) 2007, 355
3 Seiffarth (ed.) 2022: 81

primarily from engineering. The notion of communication itself, in parallel, has been mathematized (Shannon 1948).

Mathematic formulas and algorithms cannot calculate by themselves as symbols or semiotic sign systems. The digital has to become "analogue" in order to act as signal-processing medium, inviting to rethink - or even dialectically transcend - the familiar "opposition between analogical and digital"[4] in favour of a more entangled relation between logical coding and technical matter. With its focus on the mathematical models, current theory of AI / ML neglects the actual technical implementation of artificial neural nets. They are not simply logical reasoning, but techno-logical beings, which invite for matter itself to (co-)calculate. That reminds of the difference between the abstract Turing machine (as designed in 1936), and its electronic implementation as actual *computing*.

Both the physical, nonlinear world and computation itself (Fazi) are incomplete in terms of the Turing machine in principle. Therefore Turing, in his PhD thesis, added "a class of Turing type machines which have the further feature that they can, at certain points of the calculation, ask questions of a second 'oracular' device, and use the answers in further calculations"[5] - without actually specifying this mythic mechanism. Verbally coded "oracles" are the techno*lógos* of that real world. In material practice, any computation is rather infected by frictions, "noise and malfunction" (355). The logocentric mathematical idealism of the algorithm becomes techno-logic once it is hard-wired into the impure material and energetically entropic world of electronic computers.[6]

"Emergence"

An electrotechnical phenomenon of "emergence" has been the electric resonant circuit already, where a coil and a condenser are serially coupled. Its resulting sinusoid waves can be calculated from the values of their electric components, but not from the atoms such components consist of. In a nonlinear system, the change of the output is not proportional to the change of the input; therefore, changes in variables over time are unpredictable, especially phenomena such as solitons. The behaviour of a nonlinear system can still be approximated in mathematical terms indeed, such as linear equations. In its Laplacean

---

4 Gregory Bateson, in the discussion of Ralph Gerard, Some of the Problems Concerning Digital Notions in the Central Nervous System [1950], in: Claus Pias (ed.), Cybernetics / Kybernetik. Die Macy-Conferences 1946-1953, vol. 1, Zurich (Diaphanes) 2003, 171-202

5 Claude E. Shannon, Computers and Automata, in: Proceedings of the I.R.E. (October 1953), 1234-1241 (1236)

6 An argument of Ralf Baecker's media installation Random Access Memory from 2016, in: Seiffarth (ed.) 2022: 117

interpretation, emergent behaviour is in fact not random, but rather the effect of simple changes that cause complex effects. The criterion which separates causal explanation from emergent phenomena is time, the gap opening between accurate short-term to long-term forecasts. There might be an alternative temporality for techno*lógos* to articulate itself.

THERE IS NO "DEAD MEDIUM". On the Actuality of Analog Computing in Times of Ubiquitous Digital Computation

a) Analog Computing as Alternative Mathematics:

In accordance with McLuhan's *Laws of Media* and Thompson's *Rubbish Theory*, current media technologies become displaced by new media, then get forgotten, but after a certain delay are recovered from "waste" in a new actualization.

In that sense, the seemingly obsolete analog computing approach has recently been rediscovered by media archaeologists such as Joost Rekveld. Beyond its apparent audio-visual content, the actual medium message of his recent film *Mechanisms Common to Disparate Phenomena, #59*[7] is not a postmodern quotation of past things, but the symptom of an epistemological awareness of the limits of digital computation.[8] The good news of analog computing is that one can do mathematics with matter and engery, that is: "nature" itself.

The analog versus digital gap in media culture can not simply be historicized. This techno-epistemic divide does not cease to be continued, since it addresses a fundamental and insisting issue that troubled Jacques Lacan's psychoanalytics down to contemporary "speculative realism" (Karen Barad): How does the symbolic order of digital coding relate to real physical matter, and where are its limits and alternatives from the point of view of "analog" signal transduction?

The Renaissance of Analog Computing

Science fiction author Bruce Sterling has become notorious for having initiated the "Dead Media Project": a virtual remembrance of obsolete technical devices in the form of an Internet collection. This is commonly associated with "media archaeology" as artistic and academic practice-based research.

---

7 Premiered on the 23rd of May 2023 at the Eye Filmmuseum in Amsterdam

8 For a critique of the "digital" see Giuseppe Longo, Cauchemar de Promethée, xxx

While this aesthetics is still framed by the narratives and counter-narratives of cultural history, *radical* media archaeology cognizes apparently "dead" media like the analog computer in its presence as knowledge device. RMA listens to the *technológos*, that is: to the epistemic message of the analog mathematical machine in the present.

Just like geometry is an alternative way of doing mathematics against the arithmetic, the analog computer does mathematics not by numerical, discrete, algorithmic calculation but measures physical proportions by continuous operations - as it is well known from the mechanical slide rule with movable parts. A special purpose slide rule "calculates" nuclear half-time values of different matter by intervals - thereby implicitly referring to the originary linkage between nuclear research during the Cold War and analog computing, in Joost Rekveld's film:

While Rekveld's film displays the audio-visual phenotype of analog computing, "radical" media-archaeological analysis focuses on the genotypal value of this widely forgotten medium that arises *from within* the machinery.

The classical mechanical or electronic analog computer is a transitive technology: There is no numerically abstract and time-discretely sampled "software" that is symbolically hidden within microprocessors, but physical, continuous computing with the material elements itself (*techné*). Its logics (*lógos*) is no intellectual abstraction (like the "bit"), but actual hard-wired circuitry:

Fig.: Telefunken Analog Computer in the Signal Laboratory, HUB [1-Analogcomputer-Signallabor.png]

In a microscopic observation, even the digital computer, as hardware, is "analog" electronics (in the sense of Friedrich Kittler's dictum "there is no software"), but this evidence has become intransitive, for human perception, by symbolic coding and algorithms.

While the electronic analog computer has apparently become obsolete against digital computing in terms of technological history, the "analog" mathematical approach itself is no dead end. It has rather been waiting in latency to become re-discovered (even revealed) in present days as an alternative to digital computation as such: if not as practical application, but in media-epistemological perspective. Quantum computing and parallel signal processing in artificial neural nets of "deep" machine learning (a. k. a. "Artificial Intelligence") comes close to the analog computing paradigm.

In terms of permacomputing, the analog computer is much more energy-efficient than any digital data processing. But not only in environmental but in epistemological terms the analog computer deserves a renewed

attention, since it addresses the question of computational abstraction vs. transitive modelling of the physical world. The "digital" and its informational currency - the "bit" - has alienated computation from matter and energy. As it has been declared in Norbert Wiener's *Cybernetics* in 1948: "Information is information, not matter nor energy." In times of *permacomputing* though, with an "anthropocenic" concern about energy and rare earths consumption by digital devices, there is an awareness that "the distinction between the digital and the material world becomes increasingly blurred"[9].

In a book on the oxymoron of *Digital Materialities*, the editors express that the relation between research and knowing, making and interventional desig changes "in a world where the digital and the material are not separate but entangled elements of the same processes, activities and intentionalities" (ibid.). But there remains an unbridgable gap between the concept of binary information processing and real-world physical matters of activity. This has lead to a renaissance of analog computing that does mathematics not intransitively as literal transcription (sampling and quantizing of physical signals into binary code), but it is transitive to its analytic object: performing mathematics as physical computing from within the material and energetic world itself.

Within the growing field of so-called unconventional computing, the electronic analog computer is rediscovered and experienced as epistemic toy in the ancient tradition of Pythagoras' monochord. This one-string instrument has not been applied for musical entertainment (like the *kithara* / guitar) but as "phenomenotechnique" (Gaston Bachelard) or "experimental epistemology" (Warren McCulloch) to experience the *inherent*, implicit mathematics in nature itself, as it becomes apparent to the attending ear (such as the octave in its 1:2 vibrational frequency ratio).

The media-epistemological core dichotomy: physical *computing* vs. mathematical *computation*

There are two ways of computationally modeling disturbances that occur in the physical world. "With lots of computing power" one can *approximate* on chaotic system behaviour numerically", such as the Lorenz equations. Alternatively, one can implement these equations in an analog electronic circuit.[10]

---

9 Book summary of Sarah Pink / Elisenda Ardèvol / Débora Lanzeni (eds.), Digital Materialities. Design and Anthropology, London (Bloomsbury Academic) 2016 = https://www.bloomsburycollections.com/monograph?docid=b-9781474295789).

10 Web site "archive.today", entry "Build a Lorenz Attractor", https://archive.ph/20121211081109/http://frank.harvard.edu/~paulh/mis

[In terms of history of technology and media aesthetics, the analog computer seems like a "dead medium" (Bruce Sterling) that has long been replaced (even discretely emulated[11]) by digital computing. An even more "radical" media archaeology, though, reveals the analog computer not as a simple predecessor, but as a genuine and enduring, ahistorical alternative to digital computing.]

With its core mechanism, the Operational Amplifier and its essentially cybernetic techno-episteme of negative feedback signal processing, the analog computer is doing "embodied" mathematical operations like integration and differentiation from within (electro-)physical elements themselves.[12]

Analog computer imagery that otherwise may look like geometric artworks, when deciphered with media-archaeological eyes, now speaks quite provocatively "to our algorithmic, code-heavy age" as a reminder of an alternative way of computing. "How, artists and programmers now ask, can the analog reframe the closed-off, even authoritarian aspects of digital information?"[13]

Such an almost intuitive non-numerical mathematics is not even "computing" in the discrete calculational sense.

Analog computing does not *calculate* discretely with electronic equivalents to numbers ("zero" / "one") but continuously with electric voltage for adding and subtracting, or multiplying with constant factors.

[Such electronic circuits behave electronically equivalent (compared to its mathematical notation) to physical values themselves, as technical models in (partial) analogy to physical events. This function is different for the use of analog computers in art where the voltage circuits aim at

---

c/lorenz.htm#selection-9.0-17.339, accessed April 29, 2024

11 The "trigger" for Abraham's research into chaos theory has been a digital computer graphic device, the Tektronix 4006 with its storage memory tube, for the Visual Math Project: Ralph Abraham, The Chaos Revolution: A Peronal View, in: idem / Ueda (eds.) 2000, 81-90 (87)

12 For a demonstration of "programming" an analog computer (the MEDA 42 TA, produced by Aritma / TESLA, Czechoslovakia 1973) by technical computer scientists Frank Winkler and Manfred Günther from Humboldt University Berlin (2008, in German), see https://www2.informatik.hu-berlin.de/~guenther/analog/HU_Analog_Computer.pdf

13 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800

aesthetically interesting effects - rather intuitively than by numerical analysis.[14]]

The Future of Analog Computing

[The "generative art" approach from the heroic age of cybernetics is nowadays radicalized (if not *dis*continued) by synthetic Artificial Intelligence in "Deep" Machine Learning. Text-, image-, sound and video-generative "AIsthetics"[15], with its stochastic approach (such as the Stable Diffusion software environment) is inheriting and up-dating the "generative aesthetics" computational approach from classic cybern(aesth)etics (Max Bense) indeed. Day 2 of the Generative Art Summit Berlin conference (July 4th, 2024) is devoted to the topic "From Algorithms to Artificial Intelligence".]

[Technical recursions fold cultural time "and thus enable direct contact between points and events" that are otherwise separated when media-historical time is "stretched out on a continuous line"[16].]

In that sense, a seemingly "dead" medium like the analog computer returns with a different attention for nonlinear processes with its parallel processing of signals.

[The media-archaeological alternatives to the familiar linear, narrative and progressive concepts of a techno-historical timeline are media-temporal foldings and recursions in the sense of McLuhan's *Laws of Media*. His model of "Tetrads" (as operative diagrammatics) states that a current medium, once it has been displaced by a new technology, first becomes displaced and dysfunctional, but will not disappear. "Obsolete" media unexpectedly recur in a new context. As such, the "undead" analog computer ("the anlog thing", as coined by Bernd Ulmann) returns: if not in its historical form, but in related principles such as quantum computing, "unconventional computing" (Andrew Adamatzky) and artificial neural nets for AI and "Deep" Machine Learning.]

Let us have a look at the core of machine learning: the verbal description, algebraic formulation, the diagram and the actual patch of modelling neuronal bursting,

---

14 See Herbert W. Franke, Computergraphik – Computerkunst, München (Bruckmann) 1971; 2nd enlarged edition Heidelberg (Springer) 1985, 1

15 A reference to the / Rijeka Glowing Globe festival theme AIsthEthics, October 2024

16 Geoffrey Winthrop-Young, Siren Recursions, in: Stephen Sale / Laura Salisbury (eds.), Kittler Now. Current Perspectives in Kittler Studies, Cambridge UK (Polity Press), 2015, 71-94, note 5

Fig.: "Neuronal Bursting", in: Thomas Fischer / Bernd Ulmann, THE ANALOG THING. First Steps, Berlin (anabrid) 2022, 13

followed by a photograph of the actual cable-wired "patch" on an analog computer:

Fig.: Photograph of the actual cable-wired "patch"

An exemplary hard-wired program ("patch") on the educational analog computer THE ANALOG THING simulates artificial neuron stimulation: it does not reduce brain activity to logical and binary "firing" (as suggested by McCulloch and Pitts), but comes closer to the *hybridity* of analog / digital signal transmission in the human brain (as emphasized by von Neumann).

b) Remembering "Exact Aesthetics":

Analog Computing, and the Art / Science Gap

So-called "informational aesthetics" has been declared in the 1960s and 1970s by protagonists like Abraham Moles in France, Max Bense in Germany and by Vladimir Bonacic from the New Tendencies in Zagreb. It is frequently associated with computer-generated, algorithmic imaging. But neither computer games nor graphical computer arts started with digital computing. It rather derives from experimentation with analog computers and mechanical plotters or electronic cathode ray tubes as their visual interface. This has been practised by early media artists in the heroic epoch of cybernetics like Heinrich Heidergsberger's photographic "Rhythmograms" from the mechanical oszillograph, Ben F. Laposky's "Oscillons" and Herbert W. Franke's series of black-and white film-recorded "Pendulum Oscillograms".[17] Such works are nowadays celebrated as productive entanglement of "art & science". But a rigid analysis is more critical of that happy alliance. Analog computing oscillates between generative aesthetics and scientific modelling with regards to its functional applications by humans. The medium itself, though, is indifferent towards its differential usage. As a radically nondiscursive device, the electronic analog computer is indifferent towards cultural discourses.

On the phenomenal, aesthetic surface level, in accordance with Herbert W. Franke's claim, "art actually led the way for science"[18]. But the artistic use of analog computing to produce rhythmic patterns has been a

17 See the Generative Art Summit Berlin conference, organized by the Foundation Herbert W. Franke, at the Academy of the Arts Berlin, July 3rd / 4th, 2024
18 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800

reduction of its scientific potential for aesthetic means, while its scientific application is rather related to precise research like nonlinear "chaotic" behaviour[19], such as in the case of Yoshisuke Ueda's research on chaotic phenomena with analog computers.

[Especially the "Ailes de Papillon" computer graphics[20] represent a recursion of a core "chaotic" theorem itself: the "butterfly effect"[21].]

[This becomes evident from the "off" voice in the "Prologue" of Rekveld's film *#59*, extracted from four papers (1990s / 2000s) of Yoshisuke Ueda's published memory of detecting "what are the steady states of a nonlinear system".[22]]

On November 27, 1961, Ueda "discovered" chaos as "nonlinear" behaviour during his analog computer experimentation. Only "three months later" (February 1962), this resulted in more arbitrarily composed oscillograms and rhythmic patterns.

It is a special temporal experience that goes along with analog computing: After switching on the device, Ueda had to wait around 20 minutes for the vacuum tubes to warm up and to stabilize (as explicitly expressed in the voice-over). While the digital ignores the "time of non-reality" between to switching states of a "bit", in analog computing, powered by direct current, it literally "counts".

[With the mathematical models in mind, humans focus on what occurs "during the calculations" in analog computing - suggesting the discrete ("calculi"), while the device rather operates in the continuous mode. Discrete repetition (by relays) only is added to repeat time-critical analog computing events for the slowness of human perception and cognition.]

[From the experimenter Ueda's side, a regular oscillation has been expected after configuring the mathematical formula, but a nonlinear behaviour in the asynchronic phase (the "chattered egg phenomenon") has been expressed the graphic output of his analog computer. In terms of mathematical analysis, "[p]people call chaos a new phenomenon, but is has has always been around. There's nothing new about it - only

---

19 On the "émotion esthétique" (Poincaré) and the reference to Birkhoff's papers on the laws of aesthetics that has been triggered by early experimentation with computational images of nonlinear chaotic behaviour see Christian Mira, I. Gumowski and a Toulouse Research Group in the "Prehistoric" Times of Chaotic Dynamics, in: Abraham / Ueda (eds) 2000, 95- 198 (175 seq.)
20 Mira 2000: 185, Fig. 52)
21 See Edward Lorenz, The Butterly Effect, in: Abraham / Ueda (eds.) 2000, 91-94
22 The prologue is also available as a separate short film: "Ueda's Shattered ["zerschmettert"] Egg" (2023, 14 min.)

people did not notice it."[23] It has been detected and revealed by / as techno*lógos* itself. For decades, this discovery has not even been widely noticed.]

[But the existence of "random oscillations" (true "analog" random) fundamentally diverges from pseudo-random as it occurs in / from digital computing. The artistic usage of computing is aiming at introducing the "creative" momentum into the otherwise redundant, rather boring logical aesthetics of computer graphics, by introducing pseudo-random numbers, such as for Nake's computer artwork *poly1* on monitor[24] - from which the scientific concern for *chaos* differs.]

Max Bense's generative aesthetics has not been developed for artistic reasons, but in a post-idealist effort to transform the otherwise philosophical concern for "aesthetics" (Hagel) into a scientific field. The target was to achieve a non-subjective approach to measure "aesthetic" value in mathematical "stochastics" (the term used for nonlinear chaotic phenomena *avant la lettre* "to describe the qualitative structure of phase trajectories generated by deterministic models [...] motivated by the so high complexity degree of trajectories, that from a casual point of view" - rather: causal? - "they appear to be random, without being really random. Now '*stochastic*' is only reserved for processes defined as a one-parameter family of random variale, a random variable being defined as a measurable function"[25]. This brings the field of nonlinear dynamics close to a XAI ("eXplainable Artificial Intelligence") demystification of the metaphysics of "emergence" in AIsthetics.

"Generative Art": a Byproduct of Science?

The Generative Art Summit in Berlin[26] will, next to an academic conference with and about the heroes of early computational art ("Hall of Fame"), screen computer animations from the 20th century, such as "Pixillation" by Lillian Schwartz (1970), and Herbert W. Franke's "Rotationen" (1974) from realtime vector animation.[27]

It is the Foundation Herbert W. Franke that initiates the Berlin event for commemoration indeed. The foundation's slogan is "Arts meets Science":

---

23 Yoshisuke Ueda, Strange Attractors and the Origin of Chaos, in: Abraham / idem (eds.) 2000, 23-56 (27)

24 See Frieder Nake, Ästhetik als Informationsverarbeitung (1974)

25 Mira 2000: 121

26 July 3-6, 2024, Academy of the Arts Berlin (Hanseatenweg)

27 On day 1 of the Generative Art Summit Berlin conference (July 3rd, 2024), Margit Rosen, Head of Collections and Archive at ZKM (Center for Media and Art Karlsruhe), will present "The History of Analog Computers in the Arts".

Fig.: "Logo" of Herbert W. Franke Foundation

Whereas a whole genre of artworks increasingly incorporates the appeal of science, and is happily financed by increasing "art & science" programs, the borders between aesthetic and scientific investigation are blurred. But it is not science that needs art but after the "end(s) of art" in the traditional canon (Hegel), aesthetic reason itself has turned scientific.

The *rendez-vous* of art and science is a difficult one. An archaeology of media arts reminds that analog computing - like Max Bense's "exact aesthetics" - has not been invented for artistic creation, but - like Thompson's Tide Predictor - for scientific analysis and physical simulation of dynamical events. Its main tool is not visual or auditive, but algebraic - as impressively indicated in the Herbert W. Franke foundation's graphical trademark by the equation for thermodynamical entropy.

[In the so-called Boltzmann formula S = k log W, S numerically represents entropy, W numerically represents probability and k is a universal constant. The difference between thermodynamic Boltzmann entropy and the informational Shannon (eng-)entropy articulates the epistemic drama of analog vs. digital computing indeed.]

This formula bridges the field of "exact aesthetics" and the discovery of nonlinear chaotic behaviour by electrical engineer, physicist and applied mathematician Yoshisuke Ueda's experimentation with analog computing and graphic plotters at Kyoto University, as demonstrated in the "Prologue" of Rekveld's film.[28]

[But different from analog computing for artistic pleasure ("soft" media archaeology), its application in science is not intuitive, but mathematic (the techno-epistemic reference of a more "radical" media archaeology).]

"Generative aesthetics" has been divided into "analog" and "digital" computing from the beginning. In terms of Shannon's *Mathematical theory of communication* (1948), "[t]he aim of generative aesthetics is the artificial production of probabilities of innovation or deviation from the norm."[29] Such a mathematical aesthetics "distinguishes between the 'material carrier' of a work of art and the 'aesthetic state' achieved by means of the carrier. The process is devoid of subjective interpretation and deals computationally with specific elements of the 'aesthetic state'

---

28 Ueda has been granted the EEE Gustav Robert Kirchhoff Award 2023 "[f]or the discovery of chaotic phenomena in electronic circuits and for contributions to the development of nonlinear dynamics." See Wikidata, https://www.wikidata.org/wiki/Q11359878

29 Max Bense, The projects of generative aesthetics, in: J. Reichardt, Cybernetics, art and ideas, London (Studio Vista) 1971, reproduced in: http://www.computerkunst.org/Bense_Manifest.pdf

[...]. These elements are pre-established and their appearance, distribution and formation is described in mathematical terms." (Bense) But while such a new aesthetics is numerically orientated, the analog approach is a different kind of mathematical aesthetics.

Oscillographic "Rhyhtmograms" vs. Digital Algorithm: Herbert W. Franke's Series

Media-philosophically, the analog computer insists as an alternative form of techno-logical reasoning, inviting for an epistemology and aesthetics of "thinking analog" and analog "t(h)inkering" (Erkki Huhtamo).

Even more fundamentally, a critique of "digitalization" arises from the re(con)naissance of the analog paradigm, unthinking the imperialism of digital computing in favour of "chaotic" disorder, and the nonlinearity of the microverse.

The analog / digital discontinuity already occurred within classic generative art itself. Herbert W. Franke's shift from analog to digital pattern generation stands for a drastic paradigm shift.

[Digital computation is of another nature in its alliance with Shannon's mathematical theory of communication. Fractal computer graphics, as central figure in the Herbert W. Franke Foundation's trademark, is a genuine knowledge product generated by digital computation once attached to a visual output.[30]]

Analog computing privileges rhythmic rather than recursive "algorhythmic"[31] patterns.

[The logified icon is embodied in the "machine", as it is shown in the "Prologue" of Rekveld's film: plotting curves with pen on paper. But the close-up of the X/Y plotter in action obscures whether such wave forms have been digitally created or are direct functions of analog computing.]

It is true: The classical media-artistic appeal of periodic patterns and functions (like Lissajous figures) from analog computing has already been emulated and replaced by algorithmic computation. But it is not the phenomenal aesthetics, but its alternative "alien mathematics" that keeps the analog computer alive.

René Descartes once replaced the clarity [German *Anschaulichkeit*] of geometric figures by his algebraic, analytic geometry, where the image

---

30 See Friedrich Kittler, Computergraphik. Eine halbtechnische Einführung, www.aesthetik.hu-berlin.de/medien/texte.php

31 See Shintaro Miyazaki, xxx

as phenomenon and the aesthetics of analog measuring is killed by numbers (Flusser's "universe of technical images").

As expressed by Herbert W. Franke: "Art always involves mathematics. Every image can be mathematically described."[32] But philosopher of mathematics Giuseppe Longo criticizes the "myth" of the digital for its reductist abstaction when compared with the contuinuity in micro-physical worlds. As indicated by Edmund Husser's *Krisis*, the mathematical intellect loses contact with the earthly ground of cultural techniques - while in the same year 1937, Turing published his seminal article on "computable numbers".[33] For the filed of artistic design, Otl Aicher criticized this arithmetization of geometry, while the analog computer is non-algorithmic. Whereas the oscilloscopic image is a transitive, indexical emanation of electronic signal processing, the pixel image on a computer monitor is just a re-visualization of an otherwise symbolic machine.

Fig.: "Herbert W. Franke at the analogue computer in 1954"

Herbert W. Franke's series *Oscillograms* (1954-1959, some times also called Pendulum Oscillograms are *not* algorithmic indeed.

They were created with an analogue computer instead that had been built by the Viennese physicist Franz Raimann in coordination with Franke.

[With media art, most artist do not create their aesthetic tools any more - neither hard- nor software.]

While Rekveld reminds of the military origins of analog computing, its "archaeology of knowledge" in the Foucauldean sense (1969) is less historical than epistemologically oriented. The analog computer has not been developed for aesthetic pleasure, but for "basic arithmetic operations in mathematics such as addition and subtraction, multiplication and division as well as differentiation and integration for the simulation of physical dynamics. The originary and incommensurable dichotomy between mathematics as geometry and as numerical analysis is reversed when the hard-wired equations implemented in the analog device are rendered visible by a classical medium for the demonstration of time-variable electric current[34]: "With this, the graphical elements were developed, mostly curves, combined in two-channel superposition–

---

32 From an interview with performer, the Fiducia magazine for bank executives (2012), as reproduced on the web site »Historic Quotes of the Visionary = https://art-meets-science.io/en/historical-quotes-of-herbert-w-franke, accessed April 25, 2024

33 See Friedrich Kittler, Phänomenologie versus Medienwissenschaft, http://hydra.humanities.uci.edu/kittler/istambul.html

corresponding to the ordinate and abscissa of areal representations. The output device was a cathode ray oscillograph [...]. On its screen, the [...] shape-determining parameters could be changed interactively" under immediate visual control.[35]

This enables transitive, immediate human-machine interaction vs. intransitive control of digital computation where the numerical processing literally intervenes. In terms of synchronization, this makes all the difference between "live" and "real-time" interaction a. k. a. "live coding".

"Visual music"? The Implicit Sonicity of Analog Computing

Below its apparent techno-historical obsolescence, the real message of the analog computing event is a different and actual one. What often looks like a free artistic visual abstract animation at first sight, are more fundamentally experiences co-produced "by humans and electronic circuits as its starting point"[36].

As *transitive* machine experience (different from distant machine theory), the analog computer is directly operated, like its twin, the electroacoustic synthesizer. Like with the modular music synthesizer, the computational intelligence in analog computing is no symbolic code (algorithm), but emerges from patching the electronic machine circuitry - kind of *physical computing* not in the digital, but truly material sense.

["Cousins to the tradition of visual music", Rekveld's film animations "often look something like a crystal formation or a media player visualizer, except that in previous works sound has been background element accompanying the images."[37]]

[Sound itself can be produced by the twin of the modular music synthesizer: by analog computing, as practiced by Hans Kulk.]

Joost Rekveld’s films offer "glimpses into secret patterns that underlie our physical reality. Such patterns are sonic.

---

34 See Ferdinand Braun, Ueber ein Verfahren zur Demonstration und zum Studium des zeitlichen Verlaufes variabler Ströme, in: Annalen der Physik und Chemie, vol. 60, no 1 (1897), 552-559

35 Web site "Analog computer" https://art-meets-science.io/en/herbert-w-franke-oscillograms, accessed April 25, 2024

36 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

37 film review by Alex Fields, web site "Not Reconciled", https://notreconciled.substack.com/p/nine-films-from-light-matters-202324

[His highly conceptual works are usually based in some sort of abstraction—an equation or pattern or application of chaos theory—which is then used to to generate slowly evolving visual elements."[38] His recent film, though, does not grant insight into the inner circuitry / *materealo*gical wiring of the machine; his real "dia(techno)logue" with the machine is therefore not shared with the audience.]

Beyond the explicit sound track, the *implicit* sonicity (tempoReality) of oscillatory signals below the surface can be media-archaeologically traced. The "subface" (with Frieder Nake) of what to human auditive and optical senses superficially appears as the aesthetics of "visual music" is analog computing.

[Heinrich Heidersberger's "Rhythmograms" have been experienced as implicitly sonic already.[39] A snapshot from Benjamin Heidersberger's electronic "Rhythmograms" serves a the cover illustration for a book called *Sonic time machines*.]

The "Atari Video Music" synthesizer (just like Shuya Abe's analog computer for Nam June Paik's video works from 196p) has been a vintage device for analog sound visualization indeed.

Fig.: Atari Video Music" synthesizer

The medium can be observed in operation: Atari-Video-Music.avi

[A reviewer comments: "Despite Rekveld's use of saturated colors and sprightly lines at various tempi, I found it easy to let this 'music' fade into the background of my consciousness."[40]]

[Bill Viola once defined the electronic video image itself as the "sound of one-line scanning". Its media-epistemic momentum is the principal (*en archè*) synaesthesis of electronic signal processing: the inner-technical indifference of its events towards human phenomenology of auditive or visual wave forms.]

Media-Active Archaeology: Continuing the Machine

In its shift from anthropocentric to "alien" phenomenology (Ian Bogost), Rekveld's film evolves into a nonverbal meditation on material processes,

38 film review by Alex Fields, web site "Not Reconciled", https://notreconciled.substack.com/p/nine-films-from-light-matters-202324

39 See Andrew Witt (ed.), Heinrich Heidersberger. Light Harmonies. Die Rhythmogramme, (Hatje Cantz)

40 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800

human perception and the arrow of time"[41] that is irritated by negentropy within chaos itself.

[The "ergodic time" (Aarseth) of oscillograms comes closer to the "Bergsonean time" of clouds than to mechanistic (and reversible) "Newtonean time" (Wiener 1948) indeed.]

Just like Ueda in his vintage experiments with chaotic behaviour, Rekveld is listening to the articulations from within the machine. The film is an outcome of the practice-based artistic research series "Dialogues with Machines"[42]

[combined with "a more general interest in a media archeology of analog electronics" (ibid.) and cybernetic reasoning.]
What emerges is rather a "diatechnologue". In direct contact with the analog computer, the human is confronting a nonhuman agency that nevertheless is an "objectivation of (his) mind" itself (in G. W. F. Hegel's terms).

[Rekveld's concern with electronic analog computing had two motivations - the one being a historical return, the other being a turn away from the supremacy of digital computing. "Analog computing is a way to approach computing that is very different from the thinking around Turing machines, a concept at the hart of our digital computers that seems so general that it is even hard to imagine there could be an alternative. I was fascinated to go back to a time when such alternative ways of thinking actually had a real-life existence. This seemed a productive strategy to develop a different perspective on current developments in computing and understand some of its aspects better" from an almost adversarial perspective.[43]]

[True media archaeology is not nostalgic but radically concerned with the operative presence of media technologies. In that way Rekveld has been "speculative in a more practical sense: to use that early history as a starting point for imagining other scenarios and to try to develop artistic uses of analog computing technology that were not possible or conceivable at the time it still existed."[44]]

["How would abstract animated films have been made if our image technology would have been all analog electronics? Which as yet under-

---

41 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707
42 In connection with a PhD defense in the first months of 2024 at the School of Arts, University College Ghent
43 http://www.joostrekveld.net/?p=2707
44 http://www.joostrekveld.net/?p=2707

or unexplored kinds of synthetic imagery align with the peculiar capacities of these devices?"[45]]

["In parallel with doing research on the early history of electronic analog computers, I started to restore these machines, and to learn how to use them and how to build one of my own. I restored an EAI TR-48 computer from 1963 [...], and to some extent I learned to understand and design analog electronics. Gradually I built a new machine that is roughly equivalent to the TR-48, but which uses electronic components that are much more recent. The result is an analog computer that is based on the same fundamental operations to calculate with voltages, but which is several orders of magnitude faster."[46]]

["[T]he TR-48 works extremely precisely up to around 1 KHz, the machine I built is a lot less precise but works with frequencies up to 50 MHz. The first idea was to use classical analog computing methods to generate HD video signals."[47]]

Buit sometimes technological reason (techno*lógos*) intervenes against the familiar aesthetics of Fine Arts itself.

[The vector displays of vintage analog computers, from the media artist's perspective, had one disadvantage: "it is *impossible to do complex images in colour*". Rekveld, with his interest in the materiality of signals, simply "did not want to do yet another work in black and white (such as #67 for instance)"[48]. Therefore Rekveld aquired a *stroke-to-raster converter*: "[...] essentially a kind of capture card for fast electronic signals, a device that converts these signals into a two-dimensional video image in the same way as a vector display or XY-display would display these signals on a phosphor screen. One crucial difference is that it can do colour: it does not only take the XY-signals that draw shapes by moving the ‘beam’ around on the screen, it also takes RGB signals that determine the colour of the line that is being drawn." Thereby "it became possible for me to use my analog machinery to do real-time animation in colour, enabling all kinds of new (to me) forms of visceral collaboration with machines."[49]]

Doing Chaos: Pseudo *versus* True Random

---

45 http://www.joostrekveld.net/?p=2707
46 http://www.joostrekveld.net/?p=2707
47 http://www.joostrekveld.net/?p=2707
48 http://www.joostrekveld.net/?p=2707, referring to http://www.joostrekveld.net/?p=1931. See as well Ian Bogost / Montfort, Racing the beam, on computer game animation on CRT
49 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

Rekveld pays attention to the sometimes chaotic articulations from the techNOlógos of analog computing: "Analog computers are really good at doing chaos [...] the *vector displays* [...] turn these chaotic signals into images on a phosphor screen"[50].

Max Bense and Abraham Moles "informational aesthetics" and Norbert Wiener's definition of information have been based on the mathematical (rather than thermodynamic) notion of negentropy: creating unexpected, that is: to higher degree informational (non-redundant) signals. Bense defined the "aesthetic state" of an art object as a ratio of order and complexity: physical disorder (highly informational "noise") in relation to an aesthetic order.[51] The experimental production of order from disorder or from a mixture of order and disorder divides into alternative operations in analog vs. digital computing.

The same algebraic equations of a Lorenz Attractor are materially implemented ("embodied") in analog electronics different from its numerical simulation

[- even if the symbolical machine is still electronics itself - but intransitively.[52]]

"In 1961, [...] Edward Lorenz and Yoshisuke Ueda independently discovered deterministic chaos in their computers."[53]

This techno-logical independence actually deconstructs the otherwise anthropocentric "historical context". An equi-primordial techno*lógos* is rather revealed by machines than "invented" by humans, rather "discovered" (like radio waves by Hertz et al.).

[It is the computers that literally "count" here, not their discursive embedding. Despite its technical realization in Bletchley Park, the Turing machine has been an "epistemic thing" (Rheinberger) before in a (meta-)mathematician's office.]

---

50 http://www.joostrekveld.net/?p=2707, referring to http://www.joostrekveld.net/?p=1931. See as well Ian Bogost / Montfort, Racing the beam, on computer game animation on CRT

51 Max Bense, Ästhetik und Programmierung, in: Bilder Images Digital. Computerkünstler in Deutschland 1986 (exhibition catalogue), Munich (Barke) 1986, 22-30

52 See Bernd Ulmann, Exploring chaos with analog computers, in: LINKs – Special Issue 1: Unconventional Computing, Andrew Adamatzky (ed.) 2021, 21-24

53 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707. See Paul Edwards, The Closed World; Computers and the Politics of Discourse in Cold War America, xxx

Media-historically "sensitive to this context, Rekveld "started to be intrigued by the fact that chaos was ‘officially’ discovered in the early 1960’s, at the height of the Cold War.

[Edward Lorenz discovered chaos in the weather equations that he was modeling on a small digital computer."[54] "Around the same time, Yoshisuke Ueda "discovered chaos in the equations that he was studying with a small analog computer" (ibid.).]

But what looks like a coincidence in historical perspective, is an articulation of techno*lógos*, pointing at the media-epistemologically alternative between analog and digital computing.

[For the "pure", logocentric mathematicians, it is the deductive method, that is: the algebraic equation that makes the electronic machine equivalent ("analogue") to the physical event, especially concerning differential equations for nonlinear dynamics).[55] In the computer *simulation* approach to weather prediction, e. g., "[t]he equations to be solved represent our best attempts to approximate the equations actually governing the atmorphere by equations which are compatible with present computer capabilities"[56]. For inductive, "impure"[57] technomathematicians who - in the Pythagorean tradition - rather derive mathematics from the physical behaviour of computing itself, once in/formed as electric circuits[58], the first assumption when observing chaotic attractors was "that my analog computer" - that is, the epistemogenic technique (or "toy") itself - "had gone bad"[59].]

[The double sense of the "analog/ue" is addressed here: the electronic device, and its scientific application for "simulation" in real-time; the invisible behind the oscillographic surface / plotting: inner-mathematical "knowledge" as revealed by its embodiment / enactment as computing; cp. Mandelbrot's detection of "fractal" aesthetics by computer visualization of mathematical equation.]

---

54 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

55 As it is expressed by Steve Smale, Finding a Horsehoe on the Beaches of Rio, in: Ralph Abraham / Yoshisuke Ueda, The Chaos Avant-Garde: Memories of the Early Days of Chaos Theory, Singapore et al. (World Scientific) 2000, 7-22 (8); online: https://ebookcentral.proquest.com/lib/huberlin-ebooks/reader.action?docID=1679743

56 Edward Lorenz, The Butterly Effect, in: Abraham / Ueda (eds) 2000, 91-94 (92)

57 Mira 2000: 190

58 See Mira 2000: 99 seq.

59 Yoshisuke Ueda, Reflextions of the Origin of the Broken-Egg Chaotic Attractor, in: Abraham / idem (eds.) 2000, 23-56 (27)

In the prologue of Rekveld's film *Mechanisms Common to Disparate Phenomena, #59* a drawing machine (plotter) is "creating formula-derived wave images in real time, while on the soundtrack we hear first person narration drawn from the letters and writings of Ueda Yoshisuke, [...] who created various analog computers and, when he gave them seemingly erroneous tasks, discovered what happens when some values are set and others are stochastic."[60] At the end of the extended*#59* imagery, though, no human voice but the sound-track of the machine plotter returns: the literal articulation of the analog machine as a memory of its own techno*lógos*.

Ueda's "abstract computing work produced the first 'evidence,' [...] of what became Chaos Theory"[61]. Beyond its discovery as a phenomenon, the challenge of how to address "chaos" digitally or by analog (co-physical) computing remains a metahistorical topic for media epistemology.

[Nonlinear time is expressed in the Nyquist-criterium of physical equilibrium as well as in the "chaotic" oscillations in the Chua electronic circuit. There is an *alógos* at work here, different a) from the notorious algorithmic (symbolic) "Entscheidungsproblem" that (negatively) induced the invention of the Turing machine and b) from Heisenberg's "uncertainty principle" in quantum mechanics.]

From micro- to macro-nonlinear media time, sociology of technology itself knows the diagramatic model of "chaotic" path-dependence.

["In light of this, Rekveld asks us to look once again at these abstract visual productions, understanding how their avoidance of an authorial intent -- the computers are simply following the data they're given --" - rather signal transduction, though, than algorithmic data processing - "may offer a parallel track for digitally generated information and/or artificial intelligence."[62]]

"What if we asked computers to produce unexpected meanings"[63], instead of demanding that the create logical value? AI-generated images emerge indeed on the basis of the diffusion model with is input being noise.[64]

---

60 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800
61 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800
62 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800
63 Review of Rekveld's film by Michael Sicinski: https://kemono.su/patreon/user/14177788/post/93233800
64 See Raphael Tostlebe, Zur Dramaturgie xxx, MA thesis HUB 2024

c) Analog Computing on / as Film:

Rekveld's Media Archaeology of Analog Computing, and the Cold War Context

Rekveld's film has a double - if not even split - concern with analog computing, oscillating between the techno-archaeological and the media-historical perspective.

One the historical side, the science-fiction film audio tracks of Rekveld's film #59 remind that "[o]ur computing technology emerged during the Cold War as a byproduct of the development of atomic weapons and their associated planetary surveillance systems."[65] This escalation, though, has been rather digital than analog computing. The so-called von Neumann architecture of the stored program computer has been developed for calculating the ignition of the atomic bomb.

[In between the imaginary (the psychic regime corresponding with the medium film (Kittler GFT 1986), the symbolic (digital computation as the container format of the film itself: DCP) and the real (analog computing), in film #59 (2023, 79 min., DCP), "humans, aliens and electronic devices vacillate" - in analogy to electronic oscillation itself - "between these poles of a human fever dream of planetary control on the one hand, and lively machinic chaos on the other"[66].]

"All images in the film were produced as analog electronic signals, in a re-enactment of antiquated ways of computing."

["These signals were generated using period equipment, including an analog computer from 1963, early sonar and radar oscillators, and bits from military flight simulators."]

"This film is an attempt to liberate these technologies from their problematic origins"[67] - to which media archaeology adds a liberation (even "decolonization") of technology from cultural memory and critical contemporary discourse[68] towards a true "dialogue with the machine",

---

65 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707. See Paul Edwards, The Closed World; Computers and the Politics of Discourse in Cold War America, xxx

66 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

67 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

68 See Shintaro Miyazaki, Counter-Dancing Digitality: On Commoning and Computation,

giving its techno*lógos* a voice, in a media-archaeological endeavour *versus* discourse.

This is perfectly expressed at the end of Rekveld's film where the credits are attributed to the artist ("All signals composed, conducted and edited by Joost Rekveld") but the machines are listed a co-protagonists as well: featuring an analog computer, a Tektronics oscilloscope, et al.

Rekveld's abstract for the Vimeo preview ends with the question: "What would circuits do without" human "people?" That would lead to a truly media-active theatre where the apparatus itself is the operative protagonist (as differentiated from the human body-bound performance).

[For media archaeology, there is no antiquation neither "dead media", and therefore: no "historical" technology. Instead a different media-archaeological tempoReality of technical media unfolds.]

Rekveld's film itself oscillates between a dramatic narrative "content" and its actual medium "message" (with McLuhan). On the one hand, Rekveld uses a voice-over and sound "to provide context and a running commentary on the abstract animated imagery",

[thereby for the first time in his artwork including "suggestions of narrative"[69]. The narrative seduction privileges historical contextualisation.]

"Narrative elements derived from Cold War era science fiction films set the tone, while references to radar and television scanning result in images that evoke very early computer graphics. These progressively unfold into organic calligraphies in which the negative space between the patterns becomes one of the protagonists. *Resemblances with manmade phenomena are gradually left behind*"[70], therefore rather enhancing the difference between cultural techniques of writing such as Japanese calligraphy, and electronic writing like the literal "oscillogram".

What if, in Rekveld's *#59*, the sound track (such as engineers communication during a NASA rocket launch, or the musical tracks from Science Fiction films of the Cold War era) were themselves used as input for the analog computer oscillograph, as spectrograms?

Rekveld's awareness finally flips "back" from the media-archaeological investigation into the historical mode: "But the biggest conceptual shift in the project was not caused by the capabilities of these devices, but by

---

https://doi.org/10.14619/0481

69 http://www.joostrekveld.net/?p=2707

70 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

their origin. The seller told me that this particular stroke-to-raster converter came *from a military flight-simulation facility*. It was designed to convert the analog signals that are used in the cockpits of fighter jets, translating numerical information and radar imagery into video images that could be superimposed onto landscape footage." (ibid.)]

[Rekveld had been collecting all kinds of vintage high-frequency analog equipment. "As an unintentional side effect, my studio had become a miniature image of sorts of the military-industrial complex."[71] Especially Rekveld's Tektronix plugin had served in the Los Alamos Scientific Laboratory, "the birthplace of the atomic bomb" (ibid.).]

[While Science and Technology Studies, beyond critical circuitry and code analysis, widens the scope of technological investigation to its discursive environment, cultural semiotics and entanglements with historical non-technical contexts, radical media archaeology even more strictly remains within the inner-technical borders or signal events.]

[The awareness of the military genealogy of such technical devices, though, is confusing the impact of digital and analog computing. While analog computing has been applied for flight simulators or the simulation of nuclear radioation decay, its limits is its lack of precision that literally "counts" in time-critical calculation of events like nuclear fusion or the ignition of the atomic bomb.]

[Is it precisely such imperfections and approximations that may help - in a postcolonial perspective - to cultivate procedural and plural approaches to technology?[72]]

[For electronically speeding up time-critical computation beyond the human range of computing time John von Neumann developed the so-called von Neumann architecture of computing that has been inherited down to today's ubiquitous microprocessors.]

The media-archaeological veto is that the Turing Machine has been rather invented from pure freedom of research (Turing 1937). Its military modification occurred only by necessity of decoding the German cryptographic Enigma machine in World War Two real-time.

---

71 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

72 See Clemens Apprich, When Achilles met the tortoise. Towards the problem of infinitesimals in machine learning, in: Andreas Sudmann / Anna Echterhölter / Markus Ramsauer / Fabian Retkowski / Jens Schröter / Alexander Waibel (eds.), Beyond Quantity. Research with Subsymbolic AI, Bielefeld (transcript) 2023 [series KI-Kritik / AI Critique, vol. 6], 61-74

[In order not to lose the innertechnical epistemic momentum by historiographical and archival contextualization (as practised in Cultural Studies discourse analysis), a non-historicizing approach is warranted - a applied in Rekveld's "personal variety of media-archeology" (ibid.).]

[In 2024, Rekveld's forthcoming book written as context for this film will declare how this project has helped shape his view on technology "as a form of collective memory and media-archeology as a method for conversing with it."[73]]

[Joost Rekveld's Dialogue with the Analog Machine]

In the "generative aesthetics" concept (Max Bense), the artwork is coming into existence (into being) only during signal processing (electric circuitry / algorithm). The technical *operations* of the machine come close to the non-narrative and non-semantic philosophy of so-called *performance* art here.

Philosopher and mathematician Max Bense, at Technical University in Stuttgart, explicitly claimed the necessity of a rather Foucauldean than Indiana Jones-like "archaeology" for the understanding of the technical world.[74] A theory of "technical existence" has to reveal its *arché* - not simply in the temporal sense, but regarding its fundamental principles: the escapement-controlled mechanical clock, the ideal thermodynamic Carnot cycle, Faraday's empirical and Maxwell's mathematical detection of the electromagnetic field for electrodynamics. But beyond Bense's "archaeology", Radical Media Archaeology even dispenses with the historical dimension, in favour of nonlinear, "recursive"[75] configurations of technical tempor(e)alities. But such techno-epistemological investigations can not be limited to the skills of the Humanities or the traditional Fine Arts. A minimum, at least amateurish techno-mathematical knowledge is mandatory. So does Rekveld. As a protagonist of "exact aesthetics", Max Bense, during World War II, had himself been trained in a laboratory for high frequency electromagnetic wave generation and detection.[76]

In "deep" machine learning, an AI "learns" pattern recognition from big data training. The data sets are mostly lococentrically tagged by human workers. The algorithms are (still) written by computational scientist. The aesthetic aim is anthropocentric in its bias. Media archaeology reverses that perspective in favour of what Ian Bogost calls *alien phenomenology*

---

73 Official "blurb" about Mechanisms Common to Disparate Phenomena, #59, http://www.joostrekveld.net/?p=2707

74 Bense 1949 / 1998, 136

75 Winthrop-Young 2015

76 See von Herrmann and Hoffmann 2004

(2012) - just like Rekveld's media-archaeological investigations "often take the shape of abstract films that function like alien phenomenologies"[77]. Humans learn exactly from errors in their dialogue with machines. Human-Machine-Interaction (HMI) *turns* (German "Kehre") into Machine-Human-Interaction, with an emphasis on the tecNOlogical (Dörfling) articulations from within the machine itself: a dia(techno)logue indeed.

Rekveld's techno-aesthetical exploration, as "the sensory consequences of systems of his own design", is often "inspired by forgotten corners in the history of science and technology"[78]. In the case of analog computing, such discoveries are less nostalgic than they seem at in the "dead media"-archaeological sense. The discrete mechanism of the digital algorithm is confronted with the analog materiality of the actual electronic machine.

Digital computers, while remaining identical in terms of hardware, are different machines depending on their software input. Since the coding of analog computers is not symbolical but physical recombinations themselves, their "contingent computation" (Fazi) does not derive from logical inconsistencies (the "Entscheidungsproblem") but from their open-endedness "as *material processes* or networks of interactions that are too complex to predict"[79] While the symbolic alphanumeric order (algorithms) predominantly operates within the logical sphere of deterministic machines and can therefore only compute pseudo-random, from the hard-wired entanglement of the symbolic diagram with matteReality in the "programming" of analog computers a contingent ("chaotic") nonlinear behaviour emerges - a genuine techNO*lógos* from within the machine.

Analog Computing Itself in Being vs. Recording of its Audio-Visual Phenomena

Rekveld's film focuses on the analog computing material sensuality rather than computational intelligence of the digital machine, as an attempt for a rather transitive ("intimate") and "embodied"[80] understanding of computing - which is predominantly, but not necessarily "digital" nowadays. Analog computing deserves such an reenactment for epistemological, that is: knowledge-oriented purposes.

---

77 Entry "About the author", https://wiki.ljudmila.org/Adela:_Digital_Dish_2024
78 http://www.joostrekveld.net/?page_id=2, accessed April 16, 2024
79 http://www.joostrekveld.net/?page_id=2, accessed April 16, 2024; italics W. E.
80 http://www.joostrekveld.net/?page_id=2, accessed April 16, 2024

But with Rekveld's *#59*, a media-aesthetic problem arises: Most films are just a record of the moving phenomena such oscillograms as resulting from analog computing, providing no insight into the generative mechanisms themselves - while the "live coding" practice of visual "djaying" displays the source code of the imagery coexistent with its projection "on the fly".

The cinematic projection on a screen is a katoptic light reflection. Different from such a documentation, the actual processual (rather than simply "essential") being of analog computing is experienced only from the presence and (re-)enactment of the machine. Visual action on its oscilloscope interface emanates diaoptically from within voltage-controlled action of the thermionic tube itself.

At the Berlin Generative Art Summit, some of the generative computer systems are actually on display.[81] It makes a difference indeed if an oscillogramm occurs "live" on an oscilloscope as an ephemeral message from the media itself or is recorded on film for reproduction, thereby reducing the analog computer to a simple "content" for another medium,

[replacing continuous signal processing (Viola's implicitly sonic video "time image") by a series of 24 frozen frames / sec..]

[Does media-aesthetic "artistic research" thereby turn the analog computer into an epistemic toy? There has been a long tradition of analog computing, combined with photographic registration or a coupled with a cathode-ray monitor, for media-artistic creation - as personified in Heinrich Heidersberger's mechanical pendulum "Rhythmograph" and his son Benjamin's electronic continuation.]

For Herbert W. Franke, filming has not been external to the analog computing event, but has been chrono-photographically entangled (in the Marey tradition): "Since the screen of the oscillograph was only five centimeters in diameter, the area covered by the camera was uncomfortably small. Therefore, for a series of these oscillograms, the camera with black-and-white film was moved past in space with the aperture open in front of the screen during the recording, resulting in a typical fanning out of the basic figure [...]"[82]

From an even more purist media-archaelogical view, the film presentation in the Digital Cinema Package container format itself is already an analog-to-digital conversion: pixelized voltage, filtered through compression algorithms. Once more, the sampling theorem

---

81 See https://art-meets-science.io/en/generative-art-summit-berlin

82 Web site "Analog computer" https://art-meets-science.io/en/herbert-w-franke-oscillograms, accessed April 25, 2024

assumes that continuous wave forms can be sufficiently emulated privided that their time-discrete sampling (and subsequent quantizing) surpasses at least twice the frequeny of their strongest signal components - at the price of the infinitesimal variances that occur in between. The medium message of analog computing gets lost once its visual expression is thereby subjected to the symbolic regime again. Digital aesthetics replaces the signal *aisthesis* of its material presence.

[The intelligence of the algorithmic approach is that the digital computer, by Digital Signal Processing (DSP) and according to the Shannon / Nyquist sampling theorem, can even - or just! - emulate its analog alternative.]

Instead, the media-archaeological imperative of "opening the black box" lets the analog computer, its modular configurations and its wiring ("patch) become transparent, and does not simply literally "focus" on the interface result of its signal transduction emanating (and filmed) from the oscilloscope. As audio-visual interface event, the analog computer remains opaque in the cinema projection, withdrawing into darkness behind the visual screen. In most so-called media and computer art, the mechanism "withdraws into its closed operations and conceals its being, revealing only glimpses of its inner mechanism"[83].

But at the same time in a different way of observing such visual phenomena, its implicit mathematical equations are literally "called into the light".

DOES COMPUTATION HAVE A SENSE OF ENDING?

Actual computation is both a function of the alphanumeric code, and of time-discrete clocking.[84] It has been Turing himself who advised, for digital computing machines: "Treat time as discrete."[85] Any media philosophy "in times" of ubiquitous digitallization has to regard this *en arché*.

---

83 Expressions borrowed from: Daniel K. I. Chua / Alexander Rehding, alien listening. Voyager's Golden Record and Music from Earth, New York (Zone) 2021, "Introduction: Blink Bang", 2 seq.

84 See 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

85 Alan Turing, Proposal for Development in the Mathematical Division of an Automatic Computing Engine (ACE), in: B. E. Carpenter / R. W. Doran (eds.), A. M. Turing's ACE Report of 1946 and other Papers, Cambridge, Mass., et al. (MIT Press) 1986, 20-105 (23)

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."[86] 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.

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 so-called halting problem (*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."[87] 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.[88] 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

---

86 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

87 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)

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

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*"[89] - which is the a time-discrete variance of Heidegger's ontological *being-to-death*. Computational media, therefore, are as much concerned with their own ending, as humans with their essential care of ending. Furthermore, "[o]ne of the most important aspects of algorithm design is creating an algorithm that has an efficient run-time."[90] 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*."[91] - and not simply a 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[92], 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

---

89 https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019
90 https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019
91 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, Programmieren, Kybernetik, Berlin / Boston (de Gruyter) 2019, 7-130 (50 f.)
92 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

impulse mercury delay memory for Random Access Memory in a computing machine.[93]

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.[94] 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 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[95], 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

---

93 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

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

95 Heidegger 1926 / 1979: 375

archaeology, practicing "aufweisende Grund-Freilegung"[96]. 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).

"Timed" Symbols: The Reconfigurable (Turing) Machine

In discrete computation, symbols are updated "at discrete time intervals. [...] It first gets updated at time 1, then a time 2 and so on."[97] Time itself becomes countable number in the Aristotelean sense. The world of digital computing unfolds in algorithmic step-by-step procedures, one bit at a time. Finite-state-machines are characterized by micro-moments of temporal configurations. The Turing machine scans an entry in a square

96 Heidegger 1926 / 1979: 8
97 Chris Bernhardt, Turing's Vision. the Birth of Computer Science, Cambridge, Mass. / London (The MIT Press) 2016, 83

from the paper tape, which in combination with the instruction by the command list results in a specific "*m*-configuration" *at a given time*.[98] "The behaviour of the computer at any moment is determined by the symbols which he is observing, and his 'state of mind' at that moment" (Turing 1936, section 9). The behaviour of such a machine is a linear sequence of events in time. "These events occur only at discrete 'moments' - between which nothing happens [...] like the ticking of a clock [...]."[99] This is symbolically ordered temporality, a kind of cinematographical apparatus where the read/write head takes chrono-photographic snapshots of the machine state, "up-dating" the archive in a multiple sense: different from traditional alphabetic text records, the currency of the present "archive" is "data", *numerical* bit streams.[100]

A most radical theory of storage comes from within the essence of computation itself, the *turingmachine* as described in 1937: "The machine is supplied with a 'tape' (the anlogue of paper) running through it, and divided into sections (called 'squares') each capable of bearing a 'symbol'. At any moment" - that is, in reverse of a mechanical clock - "there is just one square [...] bearing the symbol [...] which is 'in the machine'. [...] The 'scanned symbol' is the only one of which the machine is, so to speak, 'directly aware'."[101] Follows the step from one-conditional to interchangeable ("software") *archive*: "[B]y altering its *m*-configuration the machine can effectively remember some of the symbols which it has 'seen' (scanned) previously. The possible behaviour of the machine at any moment is determined by the *m*-configuration [...] and the scanned symbol" (ibid.). By their very discreteness, the machine states, if prolonged as Delta-*t*, can be understood as micro-storage, since according to Turing, the processing might at any moment be interrupted, to be resumed later.[102]

"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)

---

98 William Aspray, John von Neumann and the Origins of Modern Computing, Cambridge, Mass. / London (MIT Press) 1990, 176

99 Marvin L. Minsky, Computation. Finite and infinite machines, Englewood Cliffs, New Jersey (Prentice-Hall) 1967, 12

100 See Vilém Flusser, Die Auswanderung der Zahlen aus dem alphanumerischen Code, in: Dirk Matejowski / Friedrich Kittler (eds.), Literatur im Informationszeitalter, Frankfurt / New York (Campus) 1996, 9-14

101 Alan M. Turing, On Computable Numbers, with an Application to the Entscheidungsproblem, in: Proceedings of the London Mathematical Society, ser. 2, vol. 42 (1936/37), 230-265, section 1

102 See Warren Sack, entry "Memory", in: Matthew Fuller (ed.), Software Studies, Cambridge, MA (MIT Press) 2008, 188

ending, in "ergodic" computer games[103] 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."[104]

In works of media art, "matter" is not passive any more (such as painting on screen, or sculpture) to be in-formed in the Aristotelean sense. With computers, hardware itself becomes (en-)active by programming, since such matter is already logified.

The Computer as Chronopoet

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 meta-mathematical challenge of the computationally undecidable.[105] 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 synchronisations 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.

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

103 Aarseth 1999
104 Peter Wegner, Why interaction is more powerful than algorithms, in: Communications of the ACM, vol. 40, no. 5 (May 1997), 80-91 (83 f.)
105 Alan Turing, On Computable Numbers, with an Application to the Entscheidungsproblem, in: Proceedings of the London Mathematical Society (2), Bd. 42 (1937), 230-265

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."[106] 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."[107]

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 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[108], 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[109] 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

106 Marshall McLuhan / Eric McLuhan 1988: 53, referring to Jeremy Rifkin
107 Marshall McLuhan / Eric McLuhan 1988: 53
108 See https://en.wikipedia.org/wiki/Algorithm, accessed January 16, 2019, referring to Bolter 1984
109 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

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"[110], algorithm-driven 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'"[111] - 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 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"[112].

With the distinction between formal computation and physical computing, the question arises: "How is formal time embedded in

---

110 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

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

112 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

real?"[113], 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"[114].

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"[115].

"Smearing" Time-Discrete Computing

---

113 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

114 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

115 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

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"[116], 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

116 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

of a past in distant perspective"[117]. Historical consciousness, read this way, is the direct function of 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.

---

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

While human memory remembers the same response to the same signal, a counting function counts it different each time.[118] 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 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.[119]

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"[120] - 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.

---

118 Spencer-Brown 1994: 65

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

120 McLuhan 1964: 107

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 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."[121] 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)[122] - 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"[123]. Refering to David Bolter's *Turing's Man*[124], 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"[125] - 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.

---

121 Marshall McLuhan / Eric McLuhan 1988: 53

122 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

123 Marshall McLuhan / Eric McLuhan 1988: 53

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

125 McLuhan / McLuhan 1988: 53

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).[126] 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.

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 analogue 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

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

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[127]), 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 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

127 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.

ticking clock - by „essential“ time.[128] 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"[129], since it can not "keep up with polynomial growth rates in problem size"[130]. There are complexities which can only be dealt with in polynomial time by non-deterministic machines.[131] 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."[132] 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*"[133]; 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.[134] The way digital computers *draw a distinction* (alluding 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

128 Heidegger 1927, § 81
129 Kittler, There is No Software, 1992: 89
130 Conrad, in: Herken (ed.) 1988: 293
131 See Michael R. Garey / David S. Johnson, Computers and Intractability. A Guide to the Theory of NP-Completeness, San Francisco (Freeman) 1979
132 Kittler 1992: 89, referring to Conrad 1992: 290
133 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
134 See Claus Pias (ed.), Cybernetics - Kybernetik. The Macy Conferences 1946-1953, vol. 1: Transactions / Protokolle, Zürich / Berlin (diaphanes) 2003, 158 f.

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."[135] 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.[136] 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.

Should there be a Media Ecology of Computation?

Next to ontology, epistemology, logics and phenomenology as branches of media-philosophical reasoning, recently ethic concerns have arisen, as disguises in the name of "media ecology", or the "anthropocene". While the energy consumption and material recycling involved in computing technologies remain external to its key operator which is information, the micro-relation between informational and thermodynamical entropy (down to quantum computing) is a much more delicate one. Maxwell's demon appears not in the reading but in the erasure of information from computer memories. The historical context and individual authorship of philosophical or mathematical text composed by Leibniz, Boole or Turing "ages" in thermodynamic terms (the irreversible "historical" time arrow), but a human or non-human time-modulated reading of such texts only requires energy which is sub-critical to its informational enunciation.[137]

Algor(h)ithmic Computing and its "Musicality"

135 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

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

137 See Rolf Landauer, Information is physical, in: Physics Today (May 1991), 23-29 (25)

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 *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[138]. 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"[139]. Software belongs to the "generic objects (media)"[140]. 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"[141].]

The sono-analytic, "acoustemic"[142] approach allows to (literally) understand processual algorithmics.

Towards a Computational Epistemology of Media Tempor(e)alities

Does computation still belong to a history of technology, or is its "timeless" philosophy taking place in another tempor(e)ality? Ernst Kapp’s *Grundlinien einer Philosophie der Technik. Zur Entstehungsgeschichte der Cultur aus neuen Gesichtspunkten* (1877) ends up calling the steam engine the “machine of machines", while Karl Marx, in his so-called *Machine Fragment*, in response to Charles Babbage's economical writings (rather than to Babbage's actual computational "Engines"), even addressed the automaton. This is the point that marks the closing of the technological feedback loop: the autopoietic emancipation of technical media from their direct link to a

---

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

139 See Shintaro Miyazaki, Algorhythmics. Understanding Micro-Temporality in Computational Cultures, in: Computational Culture, Issue 2 / 2012, http://computationalculture.net/algorhythmics-understanding-micro-temporality-in-computational-cultures

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

141 Cramer 2002

142 See Steven Feld, Acoustemic Stratigraphies. Recent Work in Urban Phonography, published in: Sensate, March 2011

cultural environment. Bense called this cybernetic revolution "machine metatechnics"[143] – something that detaches itself from cultural history on its own terms. Thus media technology gains autonomy from culture, in the cybernetic marriage of machine and mathematics.

[The central exhibition of the Berlin 2023 CTM Festival for Adventurous Music & Art[144] not only featured a reconstruction of India's first electronic music studio, founded in 1969 at the National Institute of Design (NID) in Ahmedabad.[145] A "Curtained Room" aesthetically "opened" the black box of media artwork even into the algorithmic dimension of computing. Central in that space figured an animation by filmmaker Akbar Padamsee titled *Syzygy* (1969/70), a "structual experiment produced around 1969 which encrypts a hermetic geometric language through an array of dots and linear forms. Despite being entirely handmade the film employed an early code-based algorithm to determine its structures, a practice closely aligned with early generative art"[146]. That is genuine *media art*, with the creative agency being the technology itself.]

Object-oriented ontology actually rejects the privileging of human existence over the existence of non-human objects.[147] In a rather (hypothetical) media-centric view, object-oriented philosophers - somewhat in alliance with media archaeology - "maintain that objects exist independently of human perception and are not ontologically exhausted by their relations with humans or other objects"[148].

From a cult(E)urocentric perspective, a book without human reader might be a meaningless object. But in Charles Babbage's sense of computing, "logarithmic tables can be generated by a computer and be printed. These numbers may probably never be read by humans on earth."[149] but incorporate what Popper termed as "objectives knowledge". Such a computational world does not require the human subjects in order to be

---

143 Max Bense, Kybernetik oder Die Metatechnik einer Maschine, in: Ausgewählte Schriften, vol. 2: Philosophie der Mathematik, Naturwissenschaft und Technik, Stuttgart 1998, 429-446

144 27 January - 5 February 2023

145 Forthcoming: Paul Purgas (ed.), Subcontinental Synthesis. Electronic Music at the National Institute of Design, India 1969-1972, London (Strange Attractor Press) July 2023

146 Exhibition catalogue *We Found Our Own Reality*, curated by Paul Purgas, 33

147 https://en.wikipedia.org/wiki/Object-oriented_ontology; accessed 11 May 2017

148 https://en.wikipedia.org/wiki/Object-oriented_ontology, accessed 11 May 2017, referring to Graham Harman's doctoral dissertation *Tool-Being: Elements in a Theory of Objects* (Depaul University 1999)

149 Karl R. Popper, Objective Knowledge. An Evolutionary Approach [1972], Oxford, 2nd. ed. (Clarendon Press) 1979, 115

known, and indeed recalls the hypothesis of *anamnesis* in Plato's philosophical dialogue Menon. "Even though this [...] world is a human product, there are many theories in themselves and arguments in themselves [...] which have never been produced or understood and may never be produced or understood by men."[150]

In his most radical thought experiment, Popper envisions even the storage media of knowledge destroyed (like in antiquity the library of Alexandria including its philosophical machines): "there will be no re-emergence of our civilization for many milennia."[151] Machines may have been completely destroyed, but techno-mathematical machines (alias computer) are of a different kind, as expressed in Babbage's vision of the universe itself as Analytical Engine. "Knowledge in this objective sense is totally independent of anybody's claim to know."[152]

Manuel De Landa envisioned a future "robot historian"[153]; to what degree may computational machines become themselves future techno-philosophers, displacing human philosophy of technology? Technology implicitly knows more than humans who have to invent it in order to turn it into explicit knowledge.

Once human senses are coupled with an operational technological setting ("in being"), man is within its autopoietic temporal dispositive as well. This field[154] unfolds a chronotechnical regime of its own, with its almost "sonic" dynamics for so-called analogue media, or mathematical "algorhythmics" (Miyazaki), once data are processed digitally.

Such couplings create moments of literal ex-ception: Man is taken out of the man-made cultural world (which is Giambattista Vico's definition of "history") and confronts naked physics and / or pure logical reasoning.

Mathematics and technologies of computation are a core concern of contemporary media theory. That necessarily leads to anachronisms in its re-reading of technological genalogies. While so-called "analogue" media such as telephony, radio and television (based on electro-magnetic waves) had intervened in modern communication culture and apparently made obsolete the printed book culture and telegraphy, with computing, the "digital" recurred, recalling the ancient alphabetic "technologizing" of speech[155] and the discrete telegraphic code, but in a dialectically new form: processed algorithmically.

---

150 Popper 1979: 116

151 Popper 1979: 108

152 Popper 1979: 109

153 Manuel DeLanda, War in the Age of Intelligent Machines, 1991

154 "Wenn der Mensch nur dort ganz Mensch ist, wo er spielt, so wird auch er, wenn sein Mitspieler Automat ist, zum Unmenschen": Friedrich Kittler, entry "Flipper", in: Baggersee. Frühe Schriften aus dem Nachlass, ed. Tania Hron / Sandrina Khaled, Paderborn (Fink) 2015, 58 f.

Gilbert Simondon, on occasion of a conference on "machinology", once declared: "There is something eternal in a technical schema [...] and it is that which is always present and which can be preserved in a thing."[156] A media archaeology of digital "machines" (in both senses as archaeology *of* the digital and knowledge archaeology *by* digital media) reveals principles and commands (the *arché*) within the techno-mathematical field, with a focus on the innertemporal, time-critical axis, that is: the *chonopoetics* of algorithmic media, while at the same time questioning the being of technologies in culturally emphatic, symbolic, "historical" (historiographical) time.

Philosophy in time(s) of computing questions a core ontology of occidental philosophy since Greek antiquity: "time" itself. When being in an operative, signal-transducing (analog) or signal-processing (digital) state, any technology assumes autonomy and is phenomenologically "bracketed" (Husserl's term for ancient Greek *epoché*) from cultural, that is: "historical" and human time (to which software pays respect by the interfacial "interrupt" order).

The "post-computational", taken literally, refers to the challenge of preservation of digital heritage. Every digital object is a trinity of physical, logical and conceptual object.[157] Object-oriented philosophy here extends to a different epistemology of time (missed by previous philosophy of history). When extended to "deep" temporality (*alias* cultural history), the techno-logical being in the world as time-objects provides them with the option of equiprimordiality, since their actuality ("event") can be a-historically re-enacted. In that context, the emulation concept for the preservation of "post"-computational heritage (such as computer games: their hardware, their operative system, their software) represents an epistemological new concept produced by computing culture itself. With "emulation", computing culture contributes an epistemological neo-logism to contemporary philosophy of (im/material) media.

THE COMPUTATIONAL (TIME) MACHINE

The computational machine

155 Walter J. Ong, Orality and Literacy. The Technologizing of the Word [*1982], New York (Routledge) 2000

156 Gilbert Simondon, in: Cahiers du Centre Cultural Canadien No. 4 (Deuxième Colloque Sur la Mecanologie), Paris 1976, 87, translation John Hart

157 Kenneth Thibodeau, Overview of Technological Approaches to Digital Preservation and Challenges in Coming Years; http://www.clir/pubs/reports/pub107/thibodeau.html, accessed May 2017

The Turing machine operates within a "sphere of computability"[158], as a concretization of the human mind-based, but electronically extended "noosphere" in Teilhard de Chardin's sense. Such a sphere embraces everything that could possibly be executed by digital machines.

Still, any analysis of „the digital“ might start from the level of its techno-mathematical foundations, instead of philosophically musing about epistemic questions such as the dichotomy between „real“ world phenomena and their digital representations. This radical media-archaeological change of focus holds the advantage that it by-passes philosophically problematic assumptions about the „world“ or the "human mind".

Object-Oriented Ontology (such as Graham Harman's) shares its inquiry into the epistemology of matter with media archaeology, but differs from its more process-oriented definition: Technologies are in a media state only when being in operation, that is: signal processing. The essence of media only unfolds in time.

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"[159] in their different physiological channels. Among these, the amplification of

---

158 See Thomas Nückel, Berechenbarkeit als Sphäre digitaler Medien [Computability as the Sphere of Digital Media], MA thesis, Department of Media Studies, Humboldt University, Berlin, 2018. Available online: https://edoc.hu-berlin.de/handle/18452/19708

159 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

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 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'."[160]

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

---

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

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."[161]

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.[162] This time-critical souvereignty and immediacy in access means a "tactilization" of what has been non-individual 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."[163] 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.[164] The Internet thus

---

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

162 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

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

164 "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

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.[165] 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 "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.[166] 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*"[167]; 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

---

June 2010, 27 (referring to the media theory of Franco Bernardi)

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

166 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

167 McLuhan, op. cit.

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, economical and social contexts.[168] But there are are sub-"social" forces with*in* (or as a *parergon* of) technological formations.

According to Foucault, urban architectures can be reformulated as "the set of relations that define the sites of transportation, streets, trains"[169]. As a spatio-temporal 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. For such an analysis, the Kantean *a priori* fails.

Foucault's formulation of cultural communication is not the prose of humanities any more but mathematical topology, which is the real language of an *archéologie de savoir*.[170] Foucault identifies the importance of the site in a precise media-archaeological micro-analysis of *operational* space, of states in transition (a. k. a. Turing machine): "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" (Foucault 1986).

---

168 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

169 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

170 See Kusch 1989

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. 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.[171] 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."[172]

Against precise analysis close to the infrastructural data logistics[173], 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-

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

172 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

173 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"

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 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."[174]

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."[175]

[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."[176]]

The concept of calculation 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

---

174 Nakamoto 2008: chap. 3 "Timestamp Server"
175 As expressed in the "abstract" to his seminal paper "Bitcoin: A Peer-to-peer Electronic Cash System", (pseudonym) Satashi Nakamoto
176 https://bitcoin.org/bitcoin.pdf, accessed January 24, 2019

exponentially"[177]. A time-critical task: "The race between the honest chain and an attacker chain can be characterized as a Binomial Random Walk."[178]

[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.

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.[179] 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."[180] In *Le Mouvement* (1894), Marey calls the graphical curves "the language of the phenomena themselves"[181]; by analogy, Tarde defines "les études archéologiques et les études statistiques". Statistians, like the archaeologist, "jette sur les faits

---

177 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

178 Nakamoto 2008: chap. 11 "Calculations"

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

180 Tarde 1890: 122 f.

181 Quoted after Giedion 1982: 40

humains un regard tout abstrait et impersonnel"[182] - 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[183] 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, anticipating opportunities and risks "by seamlessly integrating predictive models and real-time event streams to deliver the Two-Second Advantage"[184].

"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."[185] 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.

---

182 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

183 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

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

185 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)

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).[186]

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.

---

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