TIME, TEMPERATURE, AND ITS INFORMATIONAL TURN. De-metaphorizing "temperature" in / as times of information media

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De-metaphorizing "temperature" in / as times of information media

Biased by the desire to de-metaphorize the notion of temperature when applied to contemporary digital culture, the media archaeological focus is on the term *entropy* as much as on the relation between cold storage ("thermal" objects) and hot data processing ("thermal" events).

Against the current discourse on "media ecology", let us analytically keep apart: There is temperature as infrastructural or environmental challenge (increasing heat within micro-processors, as well as energy costs for computing power); still, the core operations of binary information processing is *not* a matter of energy (Norbert Wiener), but an understanding of "temperature" turned upside down: not physical thermodynamics (Boltzmann entropy), but informational Shannon entropy.

"Entropy" has been the measure unit of the second law of thermodynamics in physics which declares that the energy disorder of any closed system tends to increase and points to an uniform equilibrium, providing the metaphysics of an "arrow of time" with a scientific ground: everything decays, since heat tends to irradiate and dissipate. For a communication media source one can say just what one would also say of a thermodynamic ensemble: When this situation is highly organized, it is not characterized by a large degree of randomness or of choice - "that is to say, the information (or the entropy) is low."[1]

In "nineteenth century" (itself a rather cloudy term, symbolically given shape by historiographical narrative), thermodynamics co-originated with "social statistics": Quetelet's *homme moyen*. And in Tarde's social statistics, information theory and sociology, for once, converge in the non-metaphorical "thermal" concept of stochastic probabilities: the statitistian, like the archeologist, „jette sur les faits humains un regard tout abstrait et impersonnel“[2] - which in present Digital Humanities returns as "social analytics" (Lev Manovich).

According to Michel Serres in *Hermes IV* , humans are immersed in "thermic noise"[3], while in technological media, thermic metaphors turn into processual materialities. Protagonist of cybernetical aesthetics Max Bense's radio play

1 Warren Weaver, Recent contributions to the Mathematical Theory of Communication (*1949), in: Claude E. Shannon / ders., The Mathematical Theory of Communication, Urbana / Chicago (University of Illinois Press) 1963, 1-28 (13)

2 Gabriel Tarde, Les lois de l´imitation, Paris 1890, chap. IV (Qu´est-ce que l´histoire?), Absatz „L´Archéologie et la Statistique“, 99 u. 114

3 Michel Serres, Der Ursprung der Sprache, in: same author, Hermes IV. Verteilung, Berlin (Merve) 1993, 278

from 1968 *Der Monolog der Terry Jo*, starts from "thermal" noise: from entropic distribution of alphabetic letters, a computer successively generates character sequences which approximate human speech.[4] The actual case is a women found in a boat after a "thermal" catastrophy: a ship naufragy at the beach of Florida: Terry Jo is unconsciously, but continuously uttering meaningless speech. Once language is identified as a stochastic process, Markov chains can start to synthesize artificial language.

a) From thermic time to informational value: Entropy between physical "medium" and techno-logical "media"

Boltzmann entropy and / or Shannon entropy

"Entropy" in transmission itself is not related to the physical temperature but to discrete sequences of impulses coded as zeros and ones. When Wiener proposed the very term "entropy" as measure of the mean probability of statistical binary decisions (bits), thereby correlating communication theory with thermodynamics[5], his student Shannon turned the term upside down. It is obviously from thermodynamics that Shannon borrowed the term of informational "entropy", which is central in his *Mathematical Theory of Communication* and until today, still is the condition of possibility for all "digital" communication media.

In the beginning, there was a demon, transforming the irreversibility of thermic time into informational atemporality. Nineteenth century physics, obscured by the clouds of industrial coal smoke, discovered the one-directedness of physical time. But even the actively "informational" observation by James Clerk Maxwell's demon is energy consuming, as demonstrated by Szilard in 1929, and Brouillon in 19xx.

Boltzmann entropy defines how distant a *physical* system is from thermodynamic equi-balance, while Shannon entropy in *communication* engineering defines how many bit-decisions, in the statistic mean, are required for the recognition of a single character from a (limited) alphabet on the sender side. Here, the very term "entropy" oscillates between physical "medium" and techno-logical "media".

In statistical "thermic" distribution over time, spatiotemporal islands against the tendency towards "heat death" emerge. In contrast to the law of increasing thermodynamic entropy, this occasionally is called "negentropic".

Electronic "temperature": the thermionic tube

4 Max Bense / Ludwig Harig, Der Monolog der Terry Jo (1968), in: Neue Hörspiel Texte / Partituren, ed. Klaus Schöning, Frankfurt/M. 1969, 57-91. See Bernhard Siegert, entry "Kulturtechnik", in: Harun Maye / Leander Scholz (eds.), Einführung in die Kulturwissenschaft, Paderborn 2011, 95-118 (112 f.)

5 Norbert Wiener, Cybernetics or control and communication in the animal and the machine, Paris (Hermann) 1948

According to Norbert Wiener in *Cybernetics* (1948), the essence of binary information is neither matter nor engergy which differentiates computation from energy-transforming machines in the 19th century. But the *actual* turingmaschine embodies both. Information is a specific measure of probabilities (where "low probability means negentropy"[6]), conceptualized in the *bit* and electronically embodied first in flip-flop circuits by means of cross-related *thermionic* tubes. By its electronic clouds, communicational Shannon entropy is enabled from within the physical vacuum as thermal Boltzmann entropy.

Fig.: Thermionic tube-shape USB memory stick

Temperature becomes non-metaphoric when detected within the core device of electronics itself: the Schrot effect in what is appropriately called "thermionic" tubes, culturally objectifying the natural wonders of thunder and lightning.[7] All technical, even digital "information" media are physical channels; here, thermal noise in the physical sense (so-called *Schrotrauschen*) interferes.

The thermionic tube as the essential non human agency of electronics (which means intelligent modulation of electricity by minimal voltage) translated energetic work into micro-energetic "temperature", the streams and clouds of electron flow within the vacuum. Especially the triode, once liberated technical media from mechanical constrains, thus from erasure in usage. Still, the tube or its subsequent functional equivalent, the transistor in semi-conducting matter, are subject to physical and chemical decay over time themselves; therefore "we are the first culture to experience our own archaeology on a daily basis"[8].

The electronic triode tube which had been developed for telegraphic, telephonic and radio signal transmission, has been mis-used as a binary switching decive in early electronic computing, forcing clouds of electron temperature (the physical real) into binary symbolic order.

The switching moment between "on" and "off" Wiener called - in an intuitive moment of epistemological poetry - the "time of non-reality" (Macy conference). But even if in theory binary information is independent from physical entropy, in each concrete implementation, this time of non-reality is real material ageing and energy-absorbing. In a truely media-archaeological operation of slowing down this moment to the extreme (von Baer), the binary switching reveals its entropic *tempoReal*.

"Sonic" time and temperature with Fourier

6 Brillouin 1951: 337

7 See Wiener, chap. "Newtonean and Bergsonean Time", in *Cybernetics* (1948)

8 Paul DeMarinis, Erased Dots and Rotten Dashes, or How to Wire Your Head for a Preservation, in: Erkki Huhtamo / Jussi Parikka (eds.), Media Archaeology. Approaches, Applications, and Implications, Berkeley / Los Angeles / London (University of California Press) 2011, 211-238 (211)

The computer literally numbers the world processually. In an algorithmic operation, Fourier Transform identifies the individual frequencies constituting the mixed signal - a "musical" analysis indeed, revealing the time-based essence of any physical signal as inaudible, sound: implicit sonicity.]

It had been a thermal hallunication indeed which initiated such kind of analytics. Joseph Fourier got its initial impulse for developing his *Theory of Heat* when being part of the scientific task force in Napoleon's Egyptian mission.[9]

Fourier('s) analysis turned implicitely "sonic" heat conduction into cold, silent (techno-)mathematical calculation. His decomposition of temperature into harmonic sine waves reaffirms the occidental epistemology of a world ordered by Pythagorean ratios, but this time in a time-based, dynamic way, and resulted in an over-profiled separation of sound from noise (for the pleasure of aesthetics). An apparently continuous thermal, that is: physical configuration is transformed into discrete computability by mathematical *analysis*. Non-periodic functions in fact can not be derived from Fourier series.[10] The real challenge to this harmonic order therefore is thermal noise and thermodynamic stochastics.

Weather as data (clouds)

Media-mathematical analysis concentrates on the non-discursive (non-cultural) articulations and is therefore radically de-metaphorizing temperature. In 1922, Lewis Fry Richardson proposed weather prediction in numerical calculation by human "computers", calculating incoming data from weather stations around the globe which are telegraphically transmitted almost in real time. A human media theatre: "Imagine a large hall like a theatre"[11], directed by a "man in charge [...] to maintain a uniform speed of progress in all parts of the globe. [...] he is like the conductor of an orchestra in which the instruments are slide-rules and calculating machines": as parallel computer architecture in real time. "[...] senior clerks [...] are collecting the future weather as fast as it is being computed [...] coded and telephoned to the radio transmitting station" <ibid.>. A transformation of thermic energy into information takes place in this "computing theatre" <ibid.>.

Hydrodynamics has been the ultimate mathematical challenge for John von Neumann, such as the nuclear fusion for the atomic bomb, resulting in more speed-efficient computing: the stored-program EDVAC architecture. Computing

9 On Fourier's Egyptian "temperature" *Urszene*, see Bernhard Siegert, Passage des Digitalen. Zeichenpraktiken der neuzeitlichen Wissenschaften 1500-1900, Berlin (Brinkmann & Bose) 2003, 249

10 See Bernhard Siegert, Passage des Digitalen. Zeichenpraktiken der neuzeitlichen Wissenschaften 1500-1900, Berlin (Brinkmann & Bose) 2003, 244

11 Fry Richardson, A Forecast Factory, in: same author, Meteorology and numerical analysis, ed. by Oliver M. Ashford et al., Cambridge / New York (Cambridge UP) 1993, 219

thermic systems belongs to the ultimate challenges of the *turingmachine* itself. With Turing machines, humanity dares to trace the real physical worlds by computational analysis and synthesis. Mathematical machines since Charles Babbage's design of an Analytic Engine aim to compute discretely the continuous dynamics with a (limited) set of real numbers, with the mathematical trick of the infinitesimal calculus (Leibniz' *limes*).

Data temperature is sublime, and the new "weather" clouds are invisible: be it Ionospheric "weather" conditions determining the signal-to-noise ratio of short wave radio communication (and electro-smog), or nuclear pollution. The digital machinery retreats into algorithmic opaqueness since nuclear testing has been substituted by the almost incomprehensible power of computational simulation.

In its interactive virtual environment *Dialogue with the Knowbotic South* (1994), the media art collective Knowbotic Research once created a three-dimensional data cloud transmitted by the measuring stations in the Antarctic; digital communication media and measuring devices produce "thermic" information "that nature never produced before" - computed nature.[12] The Antarctic as informational space actually happens outside the polar region, as artificial nature in data representations of measuring and sensoring instruments covering this area and procuding, every second, a stream, a flood of data.[13] The data body of this Cyber-Antarktica is based on temperature data and Ozone values - scientific material which has lost any deep meaning, conforming with Shannon's mathematical transformation of thermodynamic entropy into informational probabilites through communication channels. Nowadays, terms like "cloud computing" are literally obscuring the techno-mathematical theory of information communication.

b) Temperature degree zero: "cold" technological storage

Transmission and storage in media communication is conventionally kept apart. Such distinct operations, under the perspective of the temperature/energy/time equivalence, turn out as two extemes of *one* process: fast (hot) and slowed down (cooled) signal transfer.

Endurance of matter is linked to deep freeze (as expressed by the very term "permafrost" in Siberia), since the elementary molecules do not vibrate any more. Is storage an asymmetrical variety of transmission channel frozen to zero?[14] Freezing signals is an extreme slowing down, an ultimate delay of signal transmission over a channel.

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12 Christian Huebler, in: Discovering CyberAntarctic. For a curated documentation see http://www.medienkunstnetz.de/werke/dialogue-with-the-knowbotic-south (accessed September 2013); for a video documentation see http://www.youtube.com/watch?v=dJ3ZbD5uGkE (accessed September 2013

13 See Arnd Wesemann, Datenschwärme aus der Antarktis, on the installation by Knowbotic Research *Dialogue with the Knowbotic South* at Kunstraum Wien (Vienna), in: Frankfurter Rundschau, September 2, 1995. See http://www.krcf.org/krcfhome

While a "thermal" theory of signal (and data) transmission has been expressed in Shannon's "Mathematical Theory of Communication" (1948), this approach can be extended to storage as well[15], resulting in a generalized model of cultural and "social", that is: communicative tradition (as defined by Niklas Luhmann). The technologies and -logics of tradition relate to both the physical and the informational notion of "entropy" - which, in turn, allows to describe *tradition* without using the noun "time" at all, dis- and replacing it by more precise *termini technici* of operative tempor(e)alities.

Applied "entropology" of storage media

Hidden behind the user interfaces of so-called "social media", there is the regime of a physical infrastructure of data centers and the energy amount to cool such facilities; "a single data center can require more power than a medium-size town"[16].

According to the "8 degree rule", such an increasing of the temperature shortens the endurance of data storage about a half. For digital storage, information is not completely unlike energy when it comes to storage; for the storage of 1 Bit a minimal energy is necessary. Here, we come close to the Boltzmann-*Konstante*. Time vs. energy: Longer storage endurance for digital data carrier can be achieved by lower temperatures.

In a refrigerator at around 10 degree Celsius the data endurance of a typical flash memory (f. e. a USB stick) is secure for millenia[17]. But in millenia ahead, the heating of the refrigerator will have increased the earth's entropy to a deathening degree. An alternative less vulnereable to thermic conditions is the recent development of optoelectronical storage media (e. g. nanostructured glass). Such records might even survive the human race as "the last evidence of civilization"[18]. But in millenia, no being will be able to decipher a frozen electrostatic storage unit as a symbolical bit.

"Arctic" storage and the metaphorical risk: Defreezing the store and delayed transfer

14 On "time crystals", see entry "Quantenmaterie in endloser Schwingung", in: Spektrum der Wissenschaft, 6.17, 25 f.

15 See Hartmut Winkler, Prozessieren, xxx

16 See Jennifer Holt / Patrick Vonderau, "Where the Internet lives": Data Centers as Cloud Infrastructure, in: Lisa Parks / Nicole Starosielski (eds.), Signal Traffic. Critical Studies of Media Infrastructures, Urbana / Chicago / Springfield (Univ. of Illinois Pr.) 2015, 71-93 (82 f.)

17 As articulated in Chip 5/2012: 128

18 Peter G. Kazansky, supervisor of the physical optoelectronics group at the University of Southampton, Britain, quoted in an article on the "Superman memory crystal" from July 11, 2013, *online* http://rt.com/news/5d-nanostructured-glass-optics

The vocabulary of storage media is "very much a language of temperature"[19]. Low temperature has become less a metaphor for eternal memory than for delay: rather an equivalent to the electric condenser than to the archive. The time-critical counterpart of "archival" long-time preservation is condensed time in frozen water indeed; instead of endurance, we confront what Wendy Chun in terms of dynamic computer memories calls "the enduring ephemeral"[20].

In terms of technological media analysis, there is a correlation between time and temperature, speed and heat, which is not just metaphorical. Storage is a "cooled", slowed-down event - "freeze frame"[21]. In the cinematographic "moving still", endurance and processual media time are interlaced[22]

Recording is a temporal "cooling", slowing down, or even freezing, of an otherwise transient signal. Friedjof Nansen's photos from his Arctic expedition still address posterity beyond his death.

The "record" is usually associated with a cristallization or steady inscription, ranging from a paleolithic fossil, over the archival textual document, and photographic chemistry or phonographic signal engraving.[23] But there are *transitory records*, traces of a physical element like the electron left on the screen on its measuring instrument (the oscilloscope), and dynamic memory by constant regeneration like the mercury-tube based Acoustic Delay Line discussed by Alan Turing for electronic computer memory. A critical problem with such a system was thermal indeed: "the electronics required to perform the modulation, demodulation, amplification, and reshaping of the pulses was constructed mainly of vacuum tubes, and the heat given off by them would adversely affect the temperature stability of the delay lines"[24]; as a variation of the delay line for dynamic short-term storage of digital pulses, even air as memory was tried by mounting a loudspeaker on one wall of a room and a microphone on the other wall - rediscovered later in media art performance, by Alvin Lucier's notorious insteallation *I'm sitting in a room*. A. D. Booth in Britain after the Second World War, due to the lack of suitable material for electronic devices, "was forced to experiment with almost every physical property of

19 Frank / Jakobsen, thematic draft (call for papers) for the conference Archives of the Arctic. Ice, Entropy and Memory, Humboldt University, Berlin, September 18 to 21, 2013. Forthcoming in: Susanne Frank, Kjetil Jakobsen, Mandy Buschina (eds.), Archives of the Arctic, Bielefeld (transcript) 2017

20 Wendy Chun, The Enduring Ephemeral, or The Future Is a Memory, in: Erkki Huhtamo / Jussi Parikka (Hg.), Media Archaeology. Approaches, Applications, and Implications, Berkeley / Los Angeles / London (University of California Press) 2011, 184-203

21 See Stefanie Diekmann / Winfried Gerling, Freeze Frames. Zum Verhältnis von von Fotografie und Film, Bielefeld (transcript) 2010. See as well Gusztáv Hámos / Katja Pratschke / Thomas Tode (Hg.), Viva Fotofilm. bewegt/unbewegt, Marburg (Schüren) 2010

22 See David Green / Joanna Lowry (Hg.), Stillness and Time. Photography and the Moving Image, Manchester (Cornerhouse) 2006

23 Henning Genz, Wie die Zeit in die Welt kam. Die Entstehung einer Illusion aus Ordnung und Chaos, Reinbek b. H. (Rowohlt) 2002, 234 f.

24 Williams 1997: 309

matter in order to construct a working memory" for digital computing such as thermal momory: a drum whose surface was capable of being heated by a series of small wires which would locally heat a small portion and, as the drum rotated, these heated spots would pass in front of a series of heat detectors. "When a hot spot was detected, it was immediately recycled back to the writing mechanism which would copy it onto a clean (cool) part of the drum."[25]

Entropy in / as memory in computing

With digital memory, there are no more institutionally stable record repositories but dynamic *archives in motion* - a new condition which has been anticipated by the very technological nature of early digital computer working memories (RAM) for the intermedary storage of coded signals such as the mercury-based "acoustic delay line". Such instant memories were based on delay lines for the intermediary storage of coded signals, finally leading to the more enduring latency of magnetic core memory.

Practically speaking storing digital data carriers in ultra-low temperatures (be it a refrigerator or an iceberg) exponentially increases the probability for undamaged preservation. What has started as a "thermic" metaphor ("Arctic" freeze for storage), returns within the mechanism of storage itself.

Frozen water is a metaphor for slowing down the dynamic present; not yet memory, its is rather a delayed present: an equivalent to the electric condenser. Laboratory techno-physics has even produced "time crystals" where the grid is not a spatial geometry any more but unfolds in temporary patterns.[26] Permanence and endurance is not achieved in the traditional way any more (which has been monumental fixation, *stasis* so far), but by dynamic refreshing, reminiscent of the resonant circuit in electronics, consisting of a wire spool and a condensor which in delayed phase store and transmit energy as magnetic state and as electric dynamics.

Just like the phonographic record waits for the mechanic player to defreeze its analog signals in a technological act of re-presencing (Vivian Sobchack), there is a thermodynamic metaphor to express the relation of software to hardware in digital culture as well: "[t]he analogy betweeen a computer program and a musical score - once described as 'frozen music' needing only an orchestra to melt it"[27]. If this looks like a seduction by thermal metaphors, in terms of a twin "entropic" analysis in both its physical *and* informational sense, it will be justified.

25 Michael Roy Williams, A history of computing technology, 2nd ed. Los Alamitos, CA (IEEE Computer Society Press) 1997, 303

26 See Mike Beckers, Quantenmaterie in endloser Schwingung, in: Spektrum der Wissenschaft no. 6 (2017), 25 f.

27 Martin Campbell-Kelly, Past into Present: The EDSAC Simulator, in: Rojas / Hashagen (eds.) 2000: 399

[Micro-temperatures in time processing: the oscillating clock]

The Long Now Foundation in the US installs a clock meant to keep time until the next Ice Age (in around 10000 years) driven by a mechanical oscillator.[28]

But the wheel-driven mechanical clock as developed in the Benedictine monasteries of the late Medieval age is no ideal periodic oscillation, since there is an entropic dissipation implied in its material mechanism. There is no ideal pendulum, it always suffers from friction; that is why Hughens aimed at isolating (relieving) the time-giving oscillation (the pendulum's isochronism) from the actual technical realization. "Through isochronic oscillation the pendulum can exist as the autonomous embodiment of natural or physical time"[29], different from the radio controlled clock which periodically synchronize to a reference clock elsewhere. But there is always loss of energy / damped oscillation: the moment of contact between the suspended pendulum (as designed by Christiaan Huyghens to gain isochronism) and the actual clockwork. This momentum asks for desciption "in strictly thermodynamic terms, as a dissipative system." The motions of the pendulum and the moments of its contact with the escapement build "a cycle which converts potential energy to kinetic energy, and energy to information" - discrete information to answer the clock-related question "what time is it?", transforming temperature (energy) into discrete information

The interlacing of time and temperature becomes even tighter in time-keeping mechanisms with their delicate and temperature-sensitive metal elements.

Physical entropy, informational entropy and the ir/reversibility of the time arrow are interrelated in a trifold way. "Earlier centuries gave us clockwork models of the universe. A similar [...] orientation leads to the position of Zuse [...] that the universe *is* a computer"[30], where the clocking returns from within. Every discrete step in computing requires only sub-critical thermic costs.

A further escalation in this infinitesimal, itself "temporal" effort has been the *thermocompensated* piezoelectric quartz watch. Being a most exact resonator, the tuning-fork shaped quartz is still subject to a) entropical "aging as phenomenon in which the vibrational frequency of the oscillator slowly changes over time", and b) micro-ergodic ambient temperature changes (the coefficient fo thermal expansion). For most exact laboratory timekeeping, the mechanism itself might be sheltered by temperature agains environmental "temperature moods" (*temperare* in the Baroque sense): the Oven Controlled Crystal Oscillator. Another strategy is to install two crystal oscillators within one watch, with an analog compensation circuit which compensates for temperature-induced variance of frequencies by negative feedback. Here as well, the energy / information trade-off (neg/entropy) finally arrives: a major step in thermocompensation has been "the digital count adjustment method", where the crystal frequency is allowed to drift with temperature, but an independent sensor (a *thermistor*) is used to measure the exact temperature of the crystal.[31] Beyond the range of the "time of non-reality" (Norbert Wiener) inbetween

28 See Mackenzie 2001: 255, note 11
29 Mackenzie 2001: 244
30 Landauer 1991: 23

binary states, and notwithstadning the "quantizing noise" in such measuring, the minimal variances are thereby rectified. Thermic metaphors are thereby driven out of techno-logical *analysis* of time.

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31 Bruce Reding / George Palasti, In Pursuit of Perfection: Thermocompensated Quartz Watches and Their Movements; http://forums.watchuseek.com/f9/thermocompensation-methods-movements-2087.html (accessed 24 May, 2017)