REAL TIME ANALYSIS, TIME AXIS MANIPULATION

Friedrich Kittler

Translated and with an introduction by Geoffrey Winthrop-Young

Abstract **This essay traces the advances in time axis manipulation brought about by the media switches from symbolic mediation (alphabet) to analogue recording (phonography and cinematography) and digital processing (computers). Special emphasis is on the mathematical dimension of the final stage. The Fourier transform enables the conversion of sound events into periodicities with numerical values that can then be manipulated and converted back into sound events, even if there was no original source involved. The media access frequencies and operate at speeds beyond all human thresholds. Kittler argues that the resulting ability to subvert and simulate human perception is the very definition of technical media.**

Keywords **digital media, early film, Fourier transform, media theory, sound analysis, time axis manipulation**

Translator's Introduction

Real Time Analysis, Time Axis Manipulation" first appeared in 1990. The German original already came with its English title, which, as indicated in Friedrich Kittler's opening paragraph, is an act of deference. It registers the demotion of the German language in the face of the global transfer of media power from Europe and the Atlantic to the Pacific Rim arcing from Silicon Valley across to Japan and China. The essay attempts to explain this post-European geo-medial shift by telling the story of the growing intimacy between hardware and computation, inscription surfaces and binary codes.

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Passing through symbolic, analogue, and digital stages, media technologies appear to be moving ever closer to natural objects by moving ever farther away from their human subjects. But like any good tale of intimacy, it is also one of deception. The ability of digital media to store, process, and communicate levels of the real inaccessible to human perception comes at the cost of humans no longer being able to determine whether that which is allegedly processed by media is not in fact produced by them.

This is just one of the many aspects that give the essay its distinctly Kittlerian flavor. Everything you come to expect from him is on display: Lacanian asides; questionable techno-historical tidbits (see note 5); arcane literary references; ingenious jump cuts; the pillorying of everyone who argues that media are tools, extensions, or prostheses of the human; not to mention the inflationary use of adverbs and other rhetorical devices deployed to emphasize that matters are clear and simple when they are anything but. And what would a Kittler text from those days be without a cameo performance by a V-2 heading toward Britain? If the success of theory, like that of poetry, depends on firmly lodging memorable sound bites into collective discourse, then "Real Time Analysis" certainly adds to Kittler's standing as a theorist. It heads off with his second most infamous claim, "Only what is switchable is at all" (see note 2 for translation difficulties), and proceeds to deliver pithy beauties such as the assurance that metaphysics is nothing "but the confusion of data compression with a so-called essence." This is to theory what Robert Frost's better lines are to poetry. But more than in any other text, Kittler outdoes himself—almost to the point of self-parody (and maybe beyond). He gleefully unleashes a roving pack of esoteric mathematical terms and gives free rein to his fetish of higher numeracy by inserting a couple of equations that, optimistically speaking, will be understood by maybe two out of a hundred readers. Is Kittler himself one of those two? It's hard to say. Part of the essay's appeal is its Wizard of Oz component. The roller-coaster thrill of reading is enhanced by the intestinal suspicion that the author/operator may not always be in complete control of the ride.

And yet the importance of "Real Time Analysis," both for Kittler's own oeuvre as well as for a lot of work that arose in his wake, is beyond doubt. It is no coincidence that one of the best analyses of the considerable strengths (and weaknesses) of his media-theoretical contributions, Sybille Krämer's essay "The Cultural Techniques of Time Axis Manipulation: On Friedrich Kittler's Conception of Media," is a close reading of this very essay. Those eager to explore Kittler's greater depths are therefore strongly advised to consult Krämer. What follows here are just a few background pointers.

In order to grasp what is at stake, it is necessary to recall something so obvious you wonder why people ever wasted time discussing it. When Kittler first ventured into media theory, he was prone to highlight the divide between writing and analogue media. A text is not a photo or a sound recording. The latter involve inscription surfaces that capture light or sound waves bouncing off an object or emanating from a source; they process physical effects of the real. This does not apply to the symbolic domain of words—a distinction so basic that even scholars of literature came to understand it. However, like many precise insights, the appreciation of the "more realistic" performances of analogue media had an equally precise expiry date: namely, the arrival of digital simulation that allows for the rendition of nonexisting acoustic or visual objects in ways indistinguishable from the analogue reproduction of real sounds and things. Simulation—the possibility of copying a nonexistent original—problematizes the categorical divide between arbitrary referential symbol and mechanical index. Not surprisingly, Kittler performed a temporal turn. Sense and sensibility gave way to time and technicality. The implications of time storage and time axis manipulation came to take precedence over the indexical relationship between "representation" and "original." Time, Krämer explains, becomes one of the variables that can be manipulated by media technologies; and this "explanation of the technological as a modality of time management is precisely the 'main point'" (2006: 96).

However, at first glance it appears that the techno-evolutionary ruptures in time axis management are no less pronounced than those in medial reproduction. As Kittler points out, writing's possibilities of time axis reversal are very limited. Sure, you can talk like Yoda in *Star Wars*—backwards he speaks, hence German he sounds—or anadromically turn *god* into *dog* or make *rats* of *star*, but that's about it. In his autonymic retrograde fugue, Johann Sebastian Bach could turn B-A-C-H into H-C-A-B, but "how these four notes with all their overtone features were to sound when played by real instruments, Bach could neither trans- nor prescribe."[1] By contrast, analogue media enable a qualitative shift exploited by early tinkerers like Georges Méliès and Thomas Edison: defying the entropic irreversibility of time's arrow, ruins reassemble themselves back into walls, and listening to music played backward upends the way our ears identify instruments. Kittler writes, "Rather than running forward into their entropic demise, the higher complexity or structuredness of sounds emerged like a phoenix from its own ashes." Yet as impressive as analogically facilitated slow motion, speed-up, and time reversals may be, they pale in comparison to digitally enabled manipulation. Fourier series and integrals enable by way of approximation the conversion of sound events into periodicities with numerical values. The latter can then be manipulated any which way you want and converted back into sound events. Or you can start with numbers and create lifelike sound events that never occurred in real life. Your eyes and ears won't be able to tell the difference because the media involved access frequencies and operate at speeds beyond all human thresholds. Kittler came to view this transhuman dimension as the signature of technical media. They are "defined by nothing else than their strategy of subverting low frequency ranges by being able to simulate them." If Kittler had been more amicably disposed to Christian thinkers, he could have misquoted Augustine: "Homines volunt decipi; decipiantur ergo." Man is no longer the measure or master of media. With Pavlovian inevitability, this has led to charges that Kittler is a techno-determinist antihumanist. But it may be more precise to diagnose him with a case of negative anthropocentrism: the human remains the measure of all technical media insofar as the latter are defined by the inability of the former to measure them.

But here comes a crucial twist that makes Kittler's essay a harbinger of larger things and thoughts to come. No matter how pronounced the differences between alphabet, phonographs, and computers may be when it comes to the storage and manipulation of temporal sequences, no matter the ease with which digital technologies perform what no alphabet ever achieved, there is an underlying dynamic that reduces the differences between symbolic mediation, analogue reproduction, and digital processing. The operative word is *symbolic*. It must be read and used with Jacques Lacan in mind. Unfortunately, for many readers the signifier *Lacan* acts as a formidable line-skipping incentive. Just keep this in mind: when Lacan—whom Kittler always appreciated as a cybernetician with a Freudian-Saussurean veneer—spoke of symbols, he did not have in mind something defined by its ability to refer to something beyond itself (more precisely, beyond the finite set a given symbol is part of). Rather, the determining feature is substitutability *within* the set. It is internal switchability enabled by empty spaces. Yes, this is an essay about time, but one must never forget that it is spatialization that enables media, including the "pretechnical" species, to capture temporal events in the first place. And regardless of all the technological and computational leaps and bounds that will enhance and strengthen this ability, the basic dynamic remains the same. It is the manipulation of symbols that can evoke, capture, reproduce, and simulate the real. Hence the claim that now reads like an advance blurb for Kittler's unfinished *Music and Mathematics* project: "When an unknown Greek . . . proceeded to distribute the innumerable cacophony of noises emanating from human voices across twenty-four letters, when in a further step Pythagoras reduced the innumerable manifold of sounds emanating from plucking instruments to seven intervals that could be addressed by those Greek letters, and when finally Guido of Arezzo invented the staff notation for these scales, *then all this was in principle nothing but digital signal processing*" (my emphasis). Only the internally substitutable, the switchable, is at all—or at least worth—using and talking about.

Why is this so important for Kittler? Because like many a noteworthy theorist he came to stand precariously balanced on the exaggerations of his youth. He was forced to process the necessary embarrassments of his younger days, which he could neither uphold nor simply revoke. Go backward and forward in time: Kittler started out by insisting that history was a sequence of discontinuous discourse networks, a set of clearly demarcated data-processing infrastructures that could not be strung together using the usual historical metanarratives featuring the usual suspects ranging from the world spirit to the proletariat. He ended by hinting that history was a process in which these successive stages fed into each other by way of performative media feedback. In other words and names, Kittler started out as the Savonarola of media-historical ruptures and ended as the G. W. F. Hegel of media-historical recursions. The discontinuity the younger Kittler inherited from the younger Michel Foucault is maintained, but there is a traceable operational sequence that ties formerly severed times together. As already evident in the term *recursion*, this sequence resembles an algorithmic process heavily informed by Kittler's computational expertise and programming practice (further see Winthrop-Young 2015). "Time Axis Manipulation," written about the time when he purchased his first PC, is the first tentative step in this direction.

But where some ruptures are sealed, others open up (a frequent occurrence in Kittler's work). He may attempt to bring very different regimes of temporal processing under a common heading, but it comes at the price of separating human time from machine time. Foreshadowing the work of Wolfgang Ernst, "Time Axis Manipulation" revels in the technological exegesis of time-processing media, but it then adds an aside that many early readers preferred to overlook: "An era of unlimited possibilities of intervention was ushered in which by reprocessing time were able to abolish chance *and maybe even historical time itself*" (my emphasis). By rehearsing a sequence of processing levels, the essay tracks a horizontal, techno-recursive connection through time; but it does so by closing it off to the human temporal domain. Yes, Kittler tells a story, but it is located inside machines and therefore outside human history.

Real Time Analysis, Time Axis Manipulation

This manual does not attempt to explain the mathematical concepts involved in using certain coprocessor features. It assumes that you will not need to use a feature unless you understand the mathematics involved.
—Microsoft Corporation, *Macro Assembler 5.2 Manual*

What my not coincidentally English title "Real Time Analysis, Time Axis Manipulation" has in mind is to develop an up-to-date information-theoretical materialism.[2] In ten or twenty years it very likely will have to be replaced by a more foreign, namely, Japanese title, given that the industrial and practical rule of silicon technologies has already migrated to the other side of the Pacific. Nonetheless, the theory of these technologies still resides in an Indo-European language, and (once again, not coincidentally) in one which—as if it already were Japanese or Chinese—places words like *time*, *manipulation*, and *axis* next to each other without any inflection. With the caveat, then, that the envisioned practice applies only to silicon and not to future optoelectronic or organic circuits, my information-theoretical materialism will lead off with the following thesis:

Only what is switchable is at all.[3]

This excludes from the very outset spoken language: to quote Hegel's pitiless statement, sound "is a disappearing of the reality as soon as it is" (Hegel 2007: 194).

Sure, you can memorize spoken words in order to reproduce them in speech or song, but it is a great deal more challenging to place these words in a different order, for instance, by arranging them in violation of all syntactic rules from back to front. Yet the different arrangement of a stream of temporal data is precisely what is meant by time axis manipulation. Not to mention the possibility of a real time analysis that consists of decomposing the apparent phonological simplicity of sounds into their highly complex noise spectra at the same speed in which they are spoken or sung. Manipulations of order and associated analyses are far more difficult to accomplish on the time axis than in a spatial framework. Because time is first and foremost a sequential relation that allows us to equip each of its points with a cardinal number, you cannot change this order as easily as you can in space—for instance, in the board games Jacques Lacan liked to theorize about. As you know, board games feature more empty spaces than occupied ones; indeed, only if there is at least one empty space can the figures be moved at all.

This copresence of empty and full spaces is not given in time. Time axis manipulation therefore presupposes (to the horror of philosophers) that time-serial data be referred to spatial coordinates. This was already achieved in the classical depiction of physical and thus time-invariant processes by using a Cartesian system of coordinates, which features time *t* as the abscissa or *x*-axis and one of its functions (speed, acceleration, voltage, power, or whatever) as the ordinate or *y*-axis. However, it is one thing when physics limits this trick to a simple illustration; is it something altogether different when informatics realizes it in the shape of an actual circuit.

History's first such time manipulation technology was, of course, writing, especially in the shape of an alphabet that assigns a spatial position to each graphic sign representing a time-serial element in the chain of speech. Though Marshall McLuhan made this linearization responsible for all the one-sidedness of European culture, in truth and fact linearization is merely a necessary though by no means sufficient condition of written data processing. In order to intervene in a text composed of the finite elements of an alphabet, we need an empty space, the invention of which was always already implicit in that of the alphabet.[4] Neither early Greek inscriptions nor early medieval manuscripts featured separations between words. As a result, any attempt to switch the position of the letters resulted in the same forgetfulness and data loss that occurs in oral speech. The only available intermediate storage device was the inevitably fallible human memory. But once there are empty spaces between words and on margins, individual letters can be manipulated as in a Turing machine. They move to different spaces, either by disappearing from or remaining in their original place. In any case, writing equipped with separation features allows for the elementary computer operations *exchange*, *copy*, and *delete*. From crossword puzzles (see Shannon and Weaver 1964: 56–57) to palindromes, all our letter-based games rely on these operations. Poetry was probably no more and no less than their maximization.

Which is why, under the conditions of the immemorial monopoly of writing, problems arose only when it was not possible to produce a coded string of letters on paper. Graphemes can be optimized and disciplined, phonemes and dialects cannot. Intervals may be distributed across the staves and subjected to all kinds of time axis manipulation, as in the case of Johann Sebastian Bach, who composed a fugue using the letters of his own name B-A-C-H and then reversed the interval sequence to H-C-A-B. But how these four notes with all their overtone features were to sound when played by real instruments, Bach could neither trans- nor prescribe. Time axis manipulation under the condition of the monopoly of writing excluded everything that since Thomas Brown's fundamental discovery of 1830 is known as the noise of the real. You can take the word *god* and turn it around into *dog*, but that operation cannot be carried out on real gods, not to mention dogs.[5] Hydrogen molecules above absolute zero behave according to statistical laws that Brown, probably not coincidentally, discovered by coincidence and for which [Ludwig] Boltzmann found a mathematical formula. As a result, fog and all other random fabrics obey the second law of thermodynamics and inexorably move toward greater mixture and disorder. But according to [Arthur] Eddington's incisive insight, this irreversible entropy on the time axis allows us to distinguish time axis manipulation in the first place. In the case of written words like *god*, nobody (with the exception of cabbalists and intelligence experts) would think of reading it back to front as *dog*. But in the case of the well-known film trick used by Georges Méliès in *Démolition d'un mur*, in which the demolition of a wall is followed by the sequence in reverse, everybody notices the manipulation of playback time simply because in real time broken or crumbled walls do not miraculously reassemble themselves into ordered structures. Even worse, in Méliès's second time axis experiment, *La charcuterie mécanique* [*Mechanical Butcher*], a ready-made sausage, as if to mock death, transforms itself back into a pig whose slaughter is, after all, the business of butchers. Behold the resurrection of the flesh.[6]

But the mere act of seeing or recognizing time axis manipulation does not make it feasible. Under the condition of the monopoly of writing, the exact reverse took place: because and only because the time axis of contingent events could not be manipulated, every professed time axis reversal was relegated to the realm of fiction. When the empress Agrippina, the eponymous heroine of Daniel Casper von Lohenstein's 1665 tragedy, tries to persuade her son Nero to indulge in strategically rationalized incest, her highly rhetorical argument is "that the nature of things is like a compass" because "the river flows to its source" and "the sun is ever forced to run behind the dawn" (von Lohenstein [1665] 1955: 62). In compliance with these hydraulic and celestial revolutions, sons would have to sleep with their mothers. However, Agrippina's argument is an adynaton, that is, literally an impossibility. Even imperial power was unable to turn time into a compass or circle and have wombs devour their sons.

Under these circumstances, literature can do little more than obey [Roman] Jakobson's definition and bring the play of signifiers to the fabric of signifieds, thereby limiting itself to mere tales of time axis manipulation. Ilse Aichinger's *Spiegelgeschichte* (*Mirror Story*) tells the story of a life from death to birth, while *Gangarten einer nervösen Natter bei Neumond* (*Gaits of a Nervous Adder at New Moon*) manages to traverse world history from the present via Fortress Europe back to the ur-catastrophe of Atlantis and then return forward in time to the present. But while the reverse direction presents the two travelers Ulrich Sonnemann and Paul Wühr with an ordered and hence describable sequence of images, the real time analysis of history—that is, the return from Atlantis to the present—offers no more than the "confused sounds of changing millennia" (Sonnemann 1988: 144).

This aniconic realm of acoustic randomness, "for which," to quote Sonnemann, "the right to receive lies with the ear" (145), has remained the great beyond of all literature, rhetoric, and writing. It was not even ignored until other media began to feed back its randomness; and it was only at the very moment in history in which literature ceded its monopoly that it called this beyond by name. In 1897, [Stéphane] Mallarmé wrote "Un coup de dés jamais n'abolira le hazard"—a throw of the dice will never abolish chance.

Technical media accomplish with ease what no throw of the dice with twenty-six letters and one empty space will ever achieve. One or two years after Mallarmé's final dictum, the former magician (and purchaser of a Lumièreian film apparatus) Georges Méliès went to work on his pork sausage trick. At the turn of the last century, analogue media managed for the first time to store contingent time-serial events, with film in the visual and the gramophone in the acoustic domain. An era of unlimited possibilities of intervention was ushered in, which by reprocessing time were able to abolish chance and maybe even historical time itself.

But in the case of the gramophone,

these possibilities were at first somewhat limited. Once Edison's storage and replay cylinders went into series production, the time had come for voyages of discovery into the acoustic ocean (to misquote a contemporary book title): after the cornettist Jules Levy had tried to dazzle New York audiences with the speed of his passages, Edison himself turned the phonograph's cylinder to replay Levy's tunes at significantly higher speeds (Gelatt 1966: 27–28). We all know what issues from sped-up cassette recorders: frequency shifts endow even the most mediocre trumpet with brilliance; dull adagios can be accelerated to prestos. On other occasions, Edison—with a notable head start on John Lennon—experimented by playing phonographically recorded music backward. He thus achieved in the domain of the acoustically real what in the case of Bach's autonymic retrograde had been restricted to the intervals of the musically symbolic. While the retrograde had left the acoustic characteristics of the four tones B, A, C, and H unchanged, the backward replay had a decisive impact on each individual tone. As is well known, the timbre of individual instruments can be clearly distinguished from each other only during the first one hundred milliseconds of sounding forth, after which the distinguishing features rapidly diminish and vanish into a pure sinus signal devoid of any information. Listening to Edison's experiments, then, ears were able to discern only post facto—that is, when the manipulated individual tone had finally reached the point of initial blowing, bowing, or strumming—which instrument had produced it. As in the case of Méliès's time-reversal trick, [Claude] Shannon's logarithmic measure of information, the information-theoretical correlate to the second law of thermodynamics, had been turned on its head: rather than running forward into their entropic demise, the higher complexity or structuredness of sounds emerged like a phoenix from its own ashes.

Yet this is all the time axis manipulation that sound recording technologies were able to achieve prior to the introduction of the AEG magnetophone in 1940. In contrast to film with its twenty-four individual frames per second, which serve as mere temporary storage before the final editing is carried out by means of cutting and montage, the phonographic soundtrack is a read-only memory device that allows for slow motion, speed-up, and time reversals but that excludes any further manipulation. Within the confines of the read-only memories of a causal system that maintains the sequential relationship between all its points of time t (n), sound engineers have no possibility of erasing or exchanging partial sequences. In other words, randomness, while acceptable, cannot be introduced into the material itself, as writers and composers were able to do when dealing with the coded materials of writing or musical intervals. By contrast, film offers a near infinite number of manipulation techniques extending beyond slow motion and speed-up. It allows for erasures and rescriptions that turn celluloid into a read-and-write storage system, thereby endowing it with a syntax. Already in 1916, when the frame rate was still at a modest 16 hertz (provided that it could be maintained by manual cranking), the equally forgotten and magnificent Hugo Münsterberg proposed a film trick straight out of syntactic picture book:

> As soon as we give any interest to this formal aspect of the presentation, we must recognize that the photoplaywright has here possibilities to which nothing corresponds in the world of the stage. Take the case that we want to

produce an effect of trembling. We might use the pictures as the camera has taken them, sixteen in a second. But in reproducing them on the screen we change their order. After giving the first four pictures we go back to picture 3, then give 4, 5, 6, and return to 5, then 6, 7, 8, go back to 7, and so on. Any other rhythm, of course, is equally possible. The effect is one which never occurs in nature and which could not be reproduced on the stage. The events for a moment go backward. A certain vibration goes through the world like the tremolo of the orchestra. (Münsterberg 1970:55)

Münsterberg's admirable proposal equipped a sequence of random events, as is inevitably captured by any film camera, with a temporal syntax composed of parentheses, a procedure reminiscent of the conclusion of Lacan's "Seminar on the *Purloined Letter*." "[W]ith my αs, βs, γs and δs," Lacan pronounced, "I do not claim to extract from the real more than I have presupposed in its given—in other words, nothing here—but simply to demonstrate that they already bring with them a syntax by simply uniting this real into chance [*hasard*]" (Lacan 2006: 32). Münsterberg's regrettably unrealized film project would have served to reinforce the overwhelming strangeness of a random sequence by inserting syntax or periodicity: the eyes of the audience would have succumbed to the same trembling, quivering, and vertigo as the projected world. The *Gaits of a Nervous Adder at New Moon* would have been optically implemented.

In Münsterberg's day, film frames changed at a rate of sixteen per second, while today's standard is twenty-four. All old silent movies screened without the use of a special projector therefore are prey to an unwitting time axis manipulation that turns the sublime into the grotesque and parades into mass stampedes. All these effects, however, be they accidental or (as in the case of Münsterberg's proposal) carefully precalculated, still remain within perceptible frequency ranges. Today's television images, by contrast, are composed of 625 lines of 4,000 pixels each that are written onto the screen at a rate of fifty times per second. It is flat-out impossible to see individual pixels. Which is why today's color TV—with the exception of antiquated US standards—can and must use Münsterberg's trick to achieve the reverse effect: it is not a matter of making the audience tremble but of preventing the colors based on US standards from trembling, something the SECAM and PAL systems achieve by resorting to signal time delays. SECAM delays the color information for each line by exactly the amount of time it takes for the line to appear on the screen. PAL, by contrast, does not manipulate absolute time but the phase of the color signal. Technically, it poses no problem to model each crest of an oscillation as a trough and vice versa; and once this artificial phase reversal is activated for one line and switched off again for the next, the correct color signals arrive on the screen while all distortions that arose during the transmission cancel each other out, as happens when wave crest and trough coincide. Watching our screens, we encounter the paradox that time axis manipulation provides audiences between Paris and Vladivostok with the illusion that their broadcast stations are transmitting the real in real time.

And with that I am finally down to business. Barring the last one, all my examples dealt with time axis manipulation in low-frequency ranges—that is, still within range of our optical and acoustic perceptions. Technical media, however, are defined by nothing else than their strategy of subverting low-frequency ranges by being able to simulate them. Now, while it would be easy, though meaningless, to descend even lower into the continuous current domain where the frequency approaches zero and there is no possibility of temporal delay, the aforementioned strategy demands a withdrawal into high-frequency ranges beyond the scope of human eyes and ears. A throw of the dice that eliminates chance would have to be performed with infinite velocity—which is why there is no such thing. As we all know, the speed of optical or electric signals is a constant that, according to a simple equation, assigns a finite value to the maximum rate of information:

$$C_{max} = 3.7007\sqrt{\frac{P}{h}}$$

where *C* is the information flow per time unit, *P* the signal energy of the emitted photons, and *H* Planck's constant (see Chambers 1985: 199). Which is why—following Jacques Derrida—time cannot be given.

But unlike philosophy, technology allows for approximations. High-frequency technology, especially in the shape of digital signal processing [DSP], almost amounts to the gift of time. When it comes to digital signal processing, every manipulation of imperceptible points in time, which in the case of television remains a makeshift solution to disguise the worst defects of a technologically pitiful standard, is the first and last of all virtues. I will therefore allow and give myself the time to move from our familiar entertainment media, whose standards unfortunately are dictated by economics rather than technology, to the very best of what can already be achieved today.

Because only the switchable is at all, every instance of digital signal processing requires a parceling or cutting up. Inside computers, time exists only as quantified and synchronized packets whose size approaches zero. "We might say," Alan Turing stated with customary clarity in 1947, "that the clock enables us to introduce a discreteness into time, so that time for some purposes can be regarded as a succession of instants instead of a continuous flow. A digital machine must essentially deal with discrete objects" (2004: 382).[7] And to add to Turing: it was only in the wake of their computers that physicists hit upon the idea that physical time as well may consist of indivisible quanta.

The most elegant way of constructing these master frequency clocks (and I am hereby responding with three years' delay to a question raised by Hans-Dieter Bahrs) is an abuse of logic, more precisely, an abuse of the negation function. Rather than following the usual logical procedure of drawing further conclusions from a given negation, the latter is channeled back into the signal input. Due to the in principle finite transmission rate, the reversed signal arrives with a tiny delay and thus results in an opposite initial state, which in turns feeds back into the input, and so on ad infinitum. This—very un-Hegelian—negation of negation gives rise to a rhythm that allows us to cut up all nonrhythmic input signals into a microsecond rhythm. Digital signal processing may also commence, and especially that of random values. For though yes-no machines hardly occur in so-called nature (see von Neumann 1963: 298), computers have to make do with a finite number of values resulting from yes-no decisions. Decisionism is always already a part of the *machina machinarum*. The question of whether a contingent input value is larger or smaller than a specific number that can be represented within the machine determines the number used to represent the given value.

The gain we derive from whatever losses are incurred as a result of these rounding-off operations is that a finite number of steps of calculation lead to data. Digital values alone can be stored. Every throw of the dice (in Latin: each act of data processing) proves this at the strategic moment in which the dice come to rest on the table. By contrast, nothing and nobody can guarantee that the voltage stored in a capacitor or the heaps of gold locked away in a vault, insofar as they function as continuous quantities and therefore as real numbers, will not in time suffer a reduction of a few microvolts or gold atoms.

When an unknown Greek, probably in Miletus, proceeded to distribute the innumerable cacophony of noises emanating from human voices across twenty-four letters, when in a further step Pythagoras reduced the innumerable manifold of sounds emanating from plucking instruments to seven intervals that could be addressed by those Greek letters, and when, finally, Guido of Arezzo invented the staff notation for these scales, then all this was in principle nothing but digital signal processing. At least on paper, uncountable infinities shrunk down to countable finite sets. Metaphysics was nothing but the confusion of such data compression with a so-called essence, the insinuation that contingency could be absorbed by writing, sound by music, and entropy by order. Everything else—such as hair, dirt, and feces that in Plato's view most likely lacked an idea—was relegated by metaphysics into a "pit of nonsense" (Plato 1996: 131).

Digital signal processing, by contrast, appears to have been designed to process contingencies. Instead of making binary philosophical distinctions between chaos and order, it is forced to quantify an uncountable scale of intermediate stages as fuzzy logic. In other words, it has to be able to calculate in the case of each and every signal what is event (existence) and what is series (essence). As noted by Claude Shannon, the founder of the mathematical theory of information, the whole technical apparatus of communication systems wouldn't be worth the effort if it were just a matter of transmitting, storing, and processing an essence or constant (see Shannon and Weaver 1964: 31). With all respect to Niklas Luhmann, for God's unalterable Ten Commandments every church is already too much.

The entire difference between metaphysics and signal processing resides in [Harry] Nyquist's so-called sampling theorem, the mathematically precise formulation of all permissible cut-up operations. In contrast to the butchering procedure of Méliès's *La charcuterie mécanique*, pigs—these wondrous allegories of the real—may only be cut up to the point at which the discrete values can still be reconstructed into a porcine whole. In the case of time-variant signals, this means above all that the sampling frequency has to be at least twice as fast as the fastest useful signal. An SDI computer that could plot the position of Russian military satellites only in daily intervals would not be able to determine whether they are attacking westward or escaping eastward. The whole misery of our television standards resides in the ongoing violation of Nyquist's sampling theorem, which results in precisely these unwitting time reversals.

The sampling theorem is easy to follow in the case of satellites or earthquakes, whose periods measure days or even decades. The ears of the unknown Greek alphabet designer were able to discern that certain speech sounds recur after a few seconds. Difficulties begin in frequency ranges that exceed human perception thresholds, that is, in those domains where technological media operate simply because otherwise they would not be able to systematically fool our eyes and ears. For a computer to be able to speak or hear, it has to be able to analyze each individual sound much the same way the Greeks were able to analyze sound chains. In other words, it has to discover order in entropy. Take, for instance, a soprano's vowel stored in a gramophone groove. As a particular temporal and spatial point, it is nothing but a bewilderingly obscure concatenation of the singer's tones and overtones, with the admixture of all sorts of noises from the opera house and the recording surface itself. As Shannon's predecessor and colleague [Brian] Hartley unhappily concluded in confused old age, sums, like so many other mathematical expressions, have the unpleasant trait of disallowing any reconstruction of their arguments.[8] The linguistic synthesis performed by a computer, however, amounts to a linguistic analysis capable of solving this very problem of reconstruction. First, something altogether unrepeatable, such as the soprano vowel, has to be periodized; second, it has to be rendered transparent by turning it into the sum of many different periods. This is known as Fourier analysis.

Let us begin with a simple case. Using the Fourier analysis, any inherently periodic signal, such as the vibrations of a violin string, can be decomposed into a sum of individual vibrations that are simply the integer or whole-number multiples of their fundamental frequency (and thus of their sheet value). As Thomas Pynchon made clear in *The Crying of Lot 49*, the Fourier analysis hears, as it were, within one single violin tone all the innumerable, strictly mathematical violins simultaneously producing perfect sine or cosine waves, as if they were all the world's radio stations combined ([1965] 1967: 104). This microacoustic decomposition enables synthesizers to produce the timbre of violins and other traditional instruments not as the constants of an orchestra but as variables alongside countless other possible instrumental sounds. But there is more to these infinite series of sine and cosine functions (these paragons of continuous functions): it may sound paradoxical, but the discrete rectangular pulses, that is, the switching states of digital scans, may be synthesized from their exact opposite. In doing so, the Fourier series performs a mathematical magic trick from the 1820s that has since become indispensable for the computer age: it facilitates a cross-over from whole to real numbers, combinatorics to calculus.[9] Now, if signals were wholly periodic, if they were music instead of noise or prose instead of poetry, it would be possible to formalize their rules:

$$s(t) = \frac{a(0)}{2} + \sum_{f=1}^{\infty} a(f)\,cos(ft) + b(f)\sin(ft)$$

Processing nonperiodic functions, however, is more delicate; unfortunately, it is also of greater practical relevance. As opposed to the *Iliad* or the Ten Commandments, information requires "that something unknown is transmitted" (Lange 1967: 71). In principle, it cannot be formalized as a periodic sine or cosine function of a given time *t* "since the signal would then be predetermined for all future time" (72) and thus would have nothing to communicate. But then again, information cannot coincide with pure chance or white noise because in that case the only thing we learn is that no throw of the dice can abolish chance—without even being able to address that sentence in the first place. Every instance of coding from the alphabet to digital signal processing must be capable of periodizing nonperiodic functions.

In other words, we need a mathematical equivalent to [Gustave] Flaubert's haughty claim that the rules of poetry have been fixed since Homer but those of prose only since Flaubert. The chime of bells or the noise of consonants kept falling through the grids of musical theory and associated notation systems because they were not made up of whole-number sums of upper partial vibrations. In such cases, Fourier series are of no help; instead, we need to resort to Fourier integrals. Assuming that the nonperiodic itself is a sum of all possible periods between zero and infinity, all the functions of the real, physical world can be formalized:

$$F(f) = \int_{-\infty}^{\infty} (f(t)\cos(ft) + f(t)\sin(ft))\, dt$$

The infinite sum of the Fourier series is surpassed by an integral whose arguments carry through whole as well as real numbers. Obviously, this is an extremely time-consuming task that mathematicians with poor calculating skills like to avoid by presenting important integrals in closed form. However, this is of little help in the case of functions containing random elements that need to be worked out value for value. This is the sole reason why (to vary an old maxim) *navigare necesse est, vivere non necesse* [to sail is necessary; to live is not necessary], that is, why computers and cybernetics are increasingly necessary while humans have become increasingly random. Unlike mathematicians, computers are never tempted to present the Fourier integral of a noise-infested or nonperiodic function in a neatly closed form. Instead of resorting to an elegant equation that either provides a solution or does not, the blind machines perform purely numerical operations as mechanical as they are precise. And that is why, thanks to the President's Scientific Advisory Committee, the fast Fourier transform, or FTT in its beautiful American acronym, has become the standard procedure for digital signal processing (see de Coulon 1986: 8–9).

"But realities," notes Malte Laurids Brigge, "are slow and indescribably detailed" (Rilke 2008: 117). Which is why their time-based analyses, from Herodotus to [Martin] Heidegger, could merely assume the shape of historiography. This indescribability only vanishes once it is possible to transform a temporal domain into a frequency domain without any admixture of metaphysics or history of philosophy—which is exactly what FTT accomplishes. It replaces the classical time axis as the *x*-coordinate of events by a frequency axis, that is to say, an axis whose unity is inversely proportional to the unity of time. On this particular axis, everything that managed to import a residue of periodicity and order into the passage of time appears as a value on the *y*-axis. The result is a remarkably effective data compression. While a simple storage device like a CD needs about seven hundred thousand bits per second for a single stereo channel, FTT can lower the data flow per second to between five thousand and fifteen thousand.

Of course, digital signal processing has to pay for this. In order to transform a domain of time into one of frequency, it is necessary to wait until events have repeated themselves; otherwise, it wouldn't be possible to measure frequencies as inverse values of time. In the case of automated speech analysis, this means that the FTT cannot immediately determine the first frequency spectrum; instead, it has to wait for the end of a so-called window of ten to twenty milliseconds. All the sample values within that quasi-stationary window, even if someone happens to assassinate the analyzed speaker within its duration, have to be temporarily stored for later processing.

There is, then, no real time analysis of events in the sense that events are analyzed without delay. All current theories that attempt to differentiate between historical and electronic time, between delay and simultaneity, are myths. Real time analysis simply means that deferral or delay, dead time or history are processed fast enough to move on to the storage of the next time window. Ever since the introduction of electric telegraphy in 1840, which for the first time overcoded the alphabet in the shape of time signs, one short and one long, the reverse is true: according to one of Shannon's famous theorems, transmission rates can be increased by intermediate storage. Data throughput is optimized only if we do not immediately transmit the long and short telegraphic signals, but recode them on the basis of their time consumption (see Lange 1967: 182–83). The direct contrast to real time therefore is not historical time but merely simulated time, with which it is either impossible or unnecessary to keep up. John von Neumann was fully aware of this when he had one of the very first computers calculate the three-dimensional pressure waves of the first atom bombs.

In a numerical Fourier analysis, however, both the computing efforts as well as the amount of time necessary to perform them are so considerable as to prompt a search for easier operations. When the great experimenters of the nineteenth century, starting with Hermann von Helmholtz, started to tackle the physiology of the ear, they still were so enamored of Fourier's mathematical innovations that they immediately promoted ears to the status of mechanical Fourier analyzers. It was assumed that each frequency that found its way into the inner ear would encounter a resonator ready to exclusively measure its amplitude. After all, it was known since Georg Ohm that ears do not care about signal phases, that is, the point of time of its sine or cosine amplitudes. Nonetheless, Helmholtz was not able to explain how our ears solve the so-called cocktail party problem. Everybody's talking at once, and yet we only understand the other, whom the Other with capital O has assigned as our conversation partner. No resonator is able to extract one particular event from the many located on one and the same frequency band. Radios select only one frequency out of many different frequency bands, whereas the many human speeches are located somewhere between 80 and 8,000 hertz. If I had Helmholtz ears I could at best distinguish women and men the way a radio distinguishes between short wave and medium wave. Ohm's discovery, however, had already hinted at a way of overcoming this dilemma. When ears suppress phase information in order to solve the cocktail party problem, they are obviously operating in a temporal domain, unlike the Fourier analysis that centers on frequency. They do not determine possible periodicities of acoustic events but only whether there is any periodicity at all. In other words, they focus on whether after a measurable delay the received signal repeats itself. This delay has to be variable in order to be able to deal with all the frequencies within the acoustic domain. The degree of correlation has to be variable as well, for if there is a perfect correlation between different periods, as in the case of sine or cosine signals, then there would be neither innovation nor information. The only mathematical function that fulfils both criteria, and which only acquired its full status thanks to Norbert Wiener, is the autocorrelation function:

$$\phi(t,\tau) = \lim_{T \to \infty} \frac{2}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\, f(t+\tau)\, dt$$

The autocorrelation function defers any given function of time *t* by a variable time lag. It forms the product of both functions and integrates them in order to determine how similar or dissimilar events are to themselves. White noise would have the value 0, God's unalterable decalogue the value 1. If our ears are indeed mechanical autocorrelators (and a lot of physiological data supports this assumption), then they are able to outpace any Fourier analysis by recognizing vowels by their high and consonants by their low autocorrelations. The Greek inventor of the vowel alphabet, then, would have had a definite advantage. Like a crazy sound editor or a mechanical butcher, he would have needed to copy only a few millimeters of magnetic tape, place it above the original, and move it to and fro to find the greatest possible correlation between original and copy.

The fact that this act of delay itself takes up time is dromology's necessary affliction. In order to determine the frequency of an event—or bluntly put, in order to ascertain its speed—a measurement needs time; and this time has to be subtracted from the reaction time to the event in question. Conversely, in order to maximize reaction time (a recommended procedure, and not only since [Paul] Virilio's day), the measurement has to forfeit the frequency domain and like a stopwatch pinpoint this one point in time. As Samuel Weber pointed out, this is precisely what Walter Benjamin referred to as the shock, which assigns to events an absolute point in time at the price of foregoing any analysis of their content, that is, their frequency (Weber 1990).

At the conclusion of my minor excursion into popular science, we therefore may conclude that time axis analysis and frequency axis analysis are not independent of each other. Their inverse relationship forces theory to move beyond easy two-dimensional depictions located either in the temporal or in the frequency domain and instead attempt to specify events in a three-dimensional space according to time, frequency, and amplitude. This step, which is already contained in the beautiful depiction of time and its inverse function as two independent variables, was undertaken by Dennis Gabor during the Second World War. The result of his *Theory of Communication* was the elegant statement that the product of medium duration and medium frequency bandwidth cannot be arbitrarily minimized (Hagemeyer 1979: 394). In more human words: every field, that is, every event in the time-frequency diagram is a limit below which you cannot go. It is not a point. It would only be the latter if the simultaneous measurements of both time and frequency were absolutely exact. What Gabor aimed at was nothing less than the information-theoretical equivalent of [Werner] Heisenberg's quantum-physical uncertainty principle, according to which spin and position of an electron cannot be exactly determined at one and the same time.

The question that probably has been bothering you for a while is what all this signal processing mathematics is good for. Indeed, what is called measuring or, in order to remain exact and faithful to Martin Heidegger, what do computers rather than humans call measuring? This calling, Heidegger's *What Is Called Thinking?* states, is the issuing of a command. Gabor's uncertainty principle therefore borders on insubordination. But who or what issued the command?

Let us assume that Major General Ernst Kammler of the *Waffen-SS* has once again ordered that a V-2 be fired from Siegen to London. Let us further assume that the screen of a radar station in southern England is able to pick up the rocket following its burn-out just in time to warn people of the inevitable. Radar, this World War II invention, differs from analogue media like radio or television in that its signals are not continuous waves but rather square pulses of fleeting duration, which is the reason radar technology made theories of information and of data signals so necessary. The impulse encounters the V-2, which, following a short delay, acts as an unwitting sender that deflects the signal back to the radar station. Half the transit time multiplied by the speed of light yields the current distance between radar and rocket. If the latter were immobile, this would indeed amount to an absolutely precise measurement of a moment in time. Yet speed is the *differentia specifica*, the essence of the V-2 in the Porphyrian tree of World War II. As a result, temporal measurements yield statements only about unidentified flying objects without the possibility of distinguishing between friend and enemy, British Mosquitoes and Kammler's V-2s. Hence the English radar station must also measure the rocket's speed by taking into account the Doppler effect. Approaching Britain on a radial course, the V-2 shortens the temporal distance between two measurements, thereby increasing the echo frequency. But now Gabor's uncertainty principle kicks in. It determines that it is impossible to simultaneously measure both the temporal delay and the frequency shift of the approaching rocket with equal and desired exactitude.

The measure of this impossibility, which depends on the type of radar signal employed, is known by the beautiful name "ambiguity function." If we know when the rocket will arrive, we no longer know what it is; if we know what it is, we no longer know when it will arrive. But it will arrive no matter what, given that the very first differential equation solved by Konrad Zuse's computer engineering masterpiece served to optimize the servomotors of the V-2's four external rudders (see Frahm 1957: 318).

In other words, the measuring object digital signal processing responds and reacts to is another digital signal processing. DSP is not a natural science that, in line with old European models, converts the contingencies of nature into laws. As Lacan realized early on, DSP plays out in a space of double contingency (1991: 294–96): different systems, at least two of them, process each other's contingent and time-dependent events, but in doing so they use up time and thus render themselves vulnerable to each other. The winner is whoever coincidentally happens to be able to reduce the coincidences of the other faster and more effectively.

Ever since then, ever since the Peenemünde rockets and their Los Alamos payload, the law is no longer to be found in the third sura of the Quran, so that Allah willing, the hour of truth may be revealed to all women and men. The microsecond of expiry, if it can be addressed at all, appears on the first page of *Gravity's Rainbow*: "A screaming comes across the sky."

Notes

1. There are minor differences between German and English musical nomenclatures. German *B* is English *B flat* while German *H* is English *B natural*.—Trans.
2. This article first appeared in German (with its English title) in 1990. Duke University Press and *Cultural Politics* wish to thank Susanne Holl for granting the rights to publish this translation. All text in brackets is mine.—Trans.

3. I have chosen the most literal and closest way to translate "Nur was schaltbar ist, ist überhaupt," arguably the second most (in)famous statement in Kittler's oeuvre after the opening clause of *Gramophone, Film, Typewriter* ("Media determine our situation"). It is important to note that unlike the English "to switch," the German verb *schalten* does not also mean "to exchange." To reinforce Kittler's electronic thrust, the statement has on occasion been translated as "Only that which can be wired (or relayed) is at all." Some have even gone so far as to suggest, "Only that which is part of an integrated circuit is at all." With thanks to Ilinca Iurascu, Jussi Parikka, Bernhard Siegert, and Anna Tuschling.—Trans.
4. Only Benoit Mandelbrot's mathematical elegance offers an even more precise formulation: "A word is simply a sequence of proper letters terminating with an improper letter called space" (Mandelbrot 1983: 344).
5. The German original uses the untranslatable reversal of *leben* (life) into *nebel* (fog), hence the subsequent reference to fog.—Trans.
6. This passage is slightly questionable. *La charcuterie mécanique* was made by the Lumière brothers, and none of the extant copies feature the resurrectional time reversal Kittler describes. For a recent critique of Kittler's claims, see Noam Elcott (2016: 148).—Trans.
7. For the classical conception of time, see Immanuel Kant's apodictic statement: "The basis of the law is this: that neither time nor, for that matter, appearance in time consists of parts that are the smallest; and that nonetheless, as a thing changes, its state passes through all these parts, as elements, to the thing's second state" (Kant 1996: 274). It was thus not possible to transfer differential equations into the language of philosophers without producing paradoxes.
8. Personal communication from Hartley to Friedrich Hagemeyer (Berlin).
9. See [Hans] von Mangoldt/[Konrad] Knopp: "Very general classes of functions [can be] described by their Fourier series. The existence of discontinuities, or of corners or peaks of geometrical images, do not present any insurmountable obstacle. On the contrary, the ability to also represent functions with such features is an advantage trigonometric series have over other means of representation, especially power series" (1990, 540).

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Friedrich Kittler (1943–2011) studied German, philosophy, and romance studies at the University of Freiburg. He completed his PhD in 1976 and his habilitation, “Discourse Networks,” in 1984. He was professor of German at the Ruhr University in Bochum (1987–93) and subsequently appointed the chair in media aesthetics and history at the Humboldt University in Berlin (1993–2008). The key representative of German media theory, Kittler was at the forefront of the German reception of French poststructuralism and is now considered one of the most important media theorists. His studies range from the early Greek vowel alphabet to computer hardware. Several of his books have been widely translated, including *Discourse Networks 1800/1900* (1985); *Gramophone, Film, Typewriter* (1986); and *Optical Media* (1999).

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