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Irreducible parallelism - a history of the concept
Linguistic investigations in the realm of the complex

- a contribution to the debate on artificial intelligence

Joachim Paul

Research means regularly venturing to the limits of one's own understanding. Everything else is administration.

I start with a thought and see where it takes me.

Abstract

How can the concept of complexity be better grasped? In this essay, I trace the history of the term "irreducible parallelism" and attempt to show that it can serve a deeper understanding of complex systems. Starting with an anecdotal critique of the imprecise use of the concept of complexity and a discussion of the widespread anthropomorphization of AI systems in particular, I examine how parallelized, inherently serial algorithmic processes of artificial intelligence differ from the massively parallel biological processes. This approach leads to the roots of sequentiality in language, philosophy and mathematics and touches on alternative logical and mathematical approaches that are not based on a concept of linearity. In doing so, terms such as self-referentiality, self-organization and ultrametricity are discussed in order to show the limits and possibilities of the calculability and formalization of descriptions of living systems. Finally, some definitions are proposed.

Keywords: Algorithm, artificial intelligence, autopoiesis, computability, cybernetics, formalization, neural networks, proemial relation, self-organization, self-referentiality, Turing machine.

Explanatory notes: Original quotations in German have been translated, quotations from sources that are also available in English have been taken from the English translations.

Introduction via a contradiction

At a conference of the Association of German Architects (BDA) in 2016, Doris Thut remarked with reference to her professional group that "*architects* [...] *are not people who think in a theoretically precise way, they don't think precisely*." Therefore, according to the speaker, terms that are "*actually unclear*" always creep in, "*for example, the term complexity, which is actually used today for anything that is a bit difficult...*". The numerous laughs in the audience seemed to confirm her.[1]

In a way, inexact thinking affects us all; it is common practice and can be considered an element of our everyday communication. However, it may also be that this inexactitude has a precisely definable purpose, namely as a thought-provoking, linguistically groping search movement at the fringes of what is understood and on the way to new intellectual solutions to problems. (The use of terms such as fringe area naturally presupposes a spatial concept.)

Nevertheless, as explicitly stated by Doris Thut, a demand for greater precision of certain terms is justified and even necessary in specialized contexts in order to expand our knowledge and our scientific ability to perceive. It is possible that it is precisely here that the property of language as an organ of perception, as postulated by Julian Jaynes, becomes apparent.[2]

As far as a few specialized contextual uses of the term complexity are concerned, for example in complexity theory as a branch of mathematics and computer science, this specification has already been made. A specific example, a special case, is the concept of Kolmogorov complexity. However, the attributes "complex" and "particularly complicated", as indicated by Thut, are still awaiting clarification.

In (German) Wikipedia, the term "complexity", derived from the Latin "complexum", past participle passive of complecti "to entwine", "encompass" or "combine" and paraphrased with reference to Duden Online 2016, is described as "*a large number and variety of elements that are interrelated in a variety of ways, structures and processes in an overall context*".[3]

It can therefore be said that complexity in this context refers to a container with a black box character. Further properties beyond the "*manifold interrelations* [...] *in an overall context*" are neither given nor deducible.

In the current debate on "artificial intelligence", which is being conducted on an almost massive scale in the media, from trade journals to the feature pages and the tabloids, complexity is mentioned strikingly often and the attribute "complex" is used even more frequently. AI systems, it is said, are based on "*complex algorithms and neural networks*" [4], whereby the way in which these AI systems arrive at their results, often called "*decisions*", is often difficult to understand.

This can be considered a major reason for the attribution *of complexity* to AI systems. Being difficult to understand is almost synonymous with being opaque, non-transparent, and thus fits with the previously mentioned concept of the black box.

In contrast to this, however, we know that an algorithm has certain properties. It consists of a serial list of instructions and can basically be mapped onto a universal Turing machine (UTM). In principle, the term algorithm can be used synonymously with the term Turing machine in a very general sense. Further theoretical concepts, such as the so-called non-deterministic Turing machine, are explicitly not meant here.

The connectionist models known as artificial neural networks (ANNs) can be simulated as algorithms on a computer and are therefore Turing computable. These algorithms can be broken down into sub-strands due to the numerous matrix operations, each independent of each other, which can be distributed across corresponding hardware, processor networks or GPUs (graphics processing units), and run in parallel in time. However, this does not change their fundamentally serial character.

"Complex networking", on the other hand, according to Jörg Rainer Nönnig in his dissertation '*Architecture - Language - Complexity*' [5], "*increases synchronicity and thus leads to the constant weakening of cause-and-effect chains; the links between events can be constructed less and less clearly. What could be clearly "strung together" in the scientific principle of the causal nexus"*, Nönnig interjects here with a quote from the entry on the term causality in a well-known philosophy

dictionary, "*cause and effect form a chain coming from the past, running through the present and disappearing into the future"* [6] is "*now condensed into punctiform singularities."*

This paragraph by Nönnig deserves a separate critical discussion, which can be summarized by the terms "*increased synchronicity*" and "*continuous weakening of cause-and-effect chains*". It should be noted here that the above-mentioned "constructability that is *increasingly less clear*" implicitly indicates that it is a problem of the (formal) description of a system and not of the facts themselves. The use of the term *system* itself points to the aspect of construction, from ancient Greek sýn histánai = to put (something) together, to set up.[7] A system is therefore something that is put together and thus a term that – as a term – includes the process of description.

In principle, it has already been said here that complexity as a property of a system cannot be grasped algorithmically, because that presupposes a completely serial describability of the system to be described and algorithmically simulated.

Conversely, however, this means that AI systems such as artificial neural networks, which – when implemented in software – run serially on computers, never deserve to be described as *complex*. This also applies to the parallelization of these algorithms for corresponding hardware such as multi-processor systems or networks of GPUs.

The development of the brain-computer and computer-brain metaphors

was not helped by the essays and research reports by David Rumelhart, James McClelland, Geoffrey Hinton and the PDP Research Group, published in 1986 under the title "*Parallel Distributed Processing - Explorations in the Microstructure of Cognition*".[8] The two-volume work, which was enthusiastically received at the time, provided a good summary of the parallelizations of algorithmic methods for data and signal processing that had been realized to date, in addition to many other considerations and questions on the subject. It quickly became a main reference for advocates of connectionist approaches.[9]

Furthermore, in his conclusion at the end of the second volume, Donald A. Norman emphasizes that a change has taken place in interdisciplinary cooperation and that there are now serious research collaborations across many disciplinary boundaries.[10] He calls the result "*a new form of model for understanding the mechanisms of human (and animal) information processing*"[11]. He also criticizes the fact that models of psychological processing are inspired by our understanding of computers, but this statement has always been wrong. In fact, according to Norman, the so-called von Neumann architecture of the modern digital computer is strongly influenced by people's naive ideas about how the mind works. He emphasizes that with the new models at hand, this discussion can finally be set aside.[12]

In order to understand the history of the term, it should be noted that in the early days of IT, from the late 1940s to around the mid-1960s, calculating machines were often referred to as "*electronic brains*".[13] In this case, the metaphorator is the biological (human) brain and the metaphorand is the calculating machine. In the course of time, in less than 20 years, the direction of the metaphorization turned 180 degrees. Since the mid-1980s, it is not uncommon to speak of the brain as a biological computer.[14]

In his conclusion, Norman sees the new aspect as essentially the massive parallelism, which means that "*a sequence that requires millions of cycles in a conventional, serial computer can be done in a few cycles when the mechanism has hundreds of thousands of highly interconnected processors."* It goes on to say: "*These neurologically inspired computational processes pose new requirements on our understanding of computation, suggest novel theoretical explanations of psychological phenomena, and suggest powerful new architectures for the machines of the future.*"[[15]]

This sentence is reproduced here in full to show that the computer-brain metaphor, which has only just been put aside, immediately comes in through the back door again in the form of "*neurologically inspired computational processes*". This back door is unfortunately not further differentiated in the concept of parallelism.

Therefore, it is certainly also this work's fault, among other things [[16]], that in most popular science publications and, as a result, in many feature articles on the subject of artificial intelligence, a - nevertheless rough - analogy between computer and brain is still used descriptively, explainatively and argumentatively. This, however, favors the emergence of anthropomorphisms, which not infrequently serve as a driving force or background for all kinds of projections that can obscure or distort further cognitive processes.

On the other hand, if metaphors can be understood as linguistic probing tools for attempts to expand human understanding of facts, then, of course, mistakes, misinterpretations, etc. also have their raison d'être, namely as opportunities for learning processes. However, learning means that even metaphors that appear to work well at first and second glance can and must be questioned.

Among other things, we humans learn through technical construction. The philosopher Gotthard Günther wrote about this: "*If man – and to make a start somewhere – wants to understand his body as a freely moving existence within the environment, he has no choice but to repeat this body as a machine. We know without technology that we walk, but we only understand how we walk adequately when the mechanism of joints and levers no longer holds any secrets from us.*"[[17]] And Geoffrey Hinton, winner of the 2024 Nobel Prize in Physics and co-developer of the concepts of the Boltzmann and Helmholtz machines and the backpropagation algorithm, confirms exactly that when he says: "*My feeling is, if you want to understand a really complicated device like a brain you should build one.*"[[18]] It is noteworthy that Hinton speaks of the brain as a "*complicated device"* and not as a complex device.

Parallel and synchronous in networks

It is now understandable when we start with the explicitly stated intention of technically recreating our central nervous system – even if only in parts or in individual functions at first – and also that we are working with brain-computer and computer-brain analogies. In this context, one of the metaphorators is the massive parallelism of neuronal activity in biological systems at simultaneously very low clock rates, as emphasized by Norman. Here, again, a property from biology is taken as a model. The maximum firing frequency of a human neuron is around 300 Hz. In contrast, microprocessors and GPUs now operate in the GHz range. In this context, the processor cores working in parallel or the graphics processors are synchronized via a central clock generator. However, such a clock generator cannot be found in biological systems. Nevertheless, there are entire groups of so-called "*fast-spiking interneurons*" that are suspected of performing synchronization tasks.[19] But this fact alone is sufficient to indicate that the parallel processuality of computer-simulated and biological neuron networks must have completely different properties.

And it is a qualitative difference between the biological and the technical that there is or is not a central clock. We will come back to this. Further differences that can be mentioned in terms of quality lie in the structures. Computer-simulated neuronal networks have a comparatively simple structure. The individual neurons (nodes) are thought of as being arranged in successive layers or spaces (2D and 3D structure). The signal flow, for example for a network that is supposed to recognize graphic patterns or images, runs from an input layer via one or more intermediate hidden layers to the output layer. If there are multiple hidden layers in the model, this is referred to as deep learning.[20,21] As a rule, synaptic connections (weights) between neurons (nodes) only exist between neurons at different levels. Recent high-resolution imaging techniques, performed on a cubic millimeter of human neocortex, revealed that the structures there are much more complicated - not to say complex.[22]

In the currently most popular variant of artificial neural networks, the synaptic weights are corrected during the training process starting from the output backwards through the network – hence the name of the procedure, backpropagation – until the desired output of the network is achieved, or the network produces the desired classification of an image, for example. This procedure of adjusting the actual output to the desired output is also called *supervised learning*. The model architecture of the simula, the neural network, can be understood as roughly based on the biological structure of the so-called receptive field [23], in which the signals from approximately 120 million rods and 6 million cones run to about one million ganglion cells.

The method of backpropagation [24] called reverse correction of the synaptic weights through the network, however, has no physiological model. In biological nervous systems, the signals basically run in one direction only, from a neuron via its axon through one or more synaptic couplings to the dendritic trees of other neurons. The electro-chemical conduction properties of a synapse can therefore be roughly compared to a rectifier. Biological neuronal networks are consequently pure feed-forward networks. Here, too, it can be concluded that the parallelism in biological neuronal networks must be quite different from that in computer-simulated neuronal networks, which can all be reduced to serial algorithms.

Finally, for the sake of completeness, another fundamental difference should be mentioned, which is only indirectly related to parallelism. It concerns the number of possible internal states of the technical neural network on the one hand and the biological one on the other. An artificial neural network has a finite number of internal states, not least because of its nature as a digital system. However, there are a great many of these; GPT 4 from OpenAI is said to contain about a trillion parameters, each expressed by a digital floating-point number, which ultimately consists of a finite number of bits. Compared to a natural analog neuron, a digital model neuron represents a significant reduction. This applies accordingly to networks. On the technical side, we are basically dealing with a finite state machine.[25] This certainly does not apply to biology.

The problem of describing parallel processes in biology

What we can say with some certainty is that living beings, in the broadest sense, perform cognitive processes and have cognitions.[26] This includes not only sensory perception and the processes that follow, but also subsystems such as the immune system, which must be able to distinguish between self and foreign, etc. And a look into the biology and biochemistry of life, or more specifically into the internal organization of a neuron or a single living cell, shows that this difference in the parallelism of processes goes much deeper. It is fundamental and affects the "operating system" of every living cell, to deliberately use a false metaphor here. Wrong because in the context of a computer, the "operating system" is merely a piece of software. In the living cell, on the other hand, operationality is inseparable from biological matter; operationality is biological matter.

In order to clarify this difference in parallelism and make it debatable in discourse, I used a very simplified example in 2014 to describe the problem of describing the connections in the biochemistry of life processes, which I briefly stated in an essay on transhumanism: "*The genetic substance DNA serves as information for the synthesis of proteins from amino acids. It can therefore be said that DNA represents an operator that has a processual effect on the amino acids as operands, so that proteins emerge at the end of the chain. Conversely, however, we know that the genome can be repaired, for example in the event of damage. The mechanism of gene repair, for its part, consists of proteins acting on the DNA sequences. The operator-operand relationship is exactly reversed here. There is now no formally consistent operator-operand model that allows this permutation or that can comprehensively describe the overall relationship between genome and proteins.*"[[27]]

And these operator-operand relationships usually "happen" at the same time, depending on where the process conglomerate is viewed from. The "*basal separation between signifier and signified, between designator and designate, operator and operand, predetermined* by formalism, *provides a fundamental hierarchical structure that makes an irreducible representation of simultaneity and parallelism impossible in principle and forces it into the hierarchical structure of the sequence, the before and after, the linearity, the line.*[[28]]

At the 2014 annual congress (31c3) of the Chaos Computer Club in Hamburg, the cognitive scientist and philosopher Joscha Bach gave a lecture with the provocative title "*From Computation to Consciousness*"[[29]], which I attended. Consciousness is something else than cognition, although both terms can be understood as being associated with each other. However you want to describe or paraphrase consciousness, one fact should be generally accepted: a living being, a living system that can be attributed consciousness requires cognitive abilities, i.e. cognition. Conversely, a cognitive system does not necessarily have to be capable of consciousness. The ability to cognize would therefore be a basic element or necessary prerequisite for consciousness. But here the title suggests that there is a way to achieve consciousness via computation.

At the end of the very humorous and eloquent presentation, there was a round of questions. A short dialog [[30]], ensued after I briefly described the above example, pointing out the violation of Russell's type theory by the operator-operand interchange and concluded with the question of whether he believed that our currently available formal concept of mathematics and logic was sufficient to arrive at a truly constructed artificial intelligence.

Bach replied that mathematics is a kind of language in which statements such as Russell's antinomy can be produced, but that these statements do not necessarily have to make sense. He concluded with "*Computation is basically that part of mathematics that runs*", which earned him a few laughs.

He then argued for a new kind of philosophy as a branch of analytic philosophy, "*that is computational, that relies on theories that actually run.*"[31]

When I referred to the hierarchy broken by the operator-operand swap, he brought the concept of autopoiesis [32] coined by the Chilean neurobiologists Humberto Maturana and Francisco Varela into play and criticized it as unsustainable. I pointed out that autopoiesis was a primarily narrative concept without a formal claim, but that my main interest was in formalizable possibilities. He concluded by saying that he was not sure whether we needed completely new paradigms. Incidentally, this must have been a misunderstanding; in my opinion, we should not be talking about something completely new, but rather an extension of the existing. After all, you can't simply deny the success of existing formalisms.

Although Bach carefully left this question of new paradigms open, I got the impression that a kind of repression was at work or that there was an unspoken prohibition of questions to the effect that nothing else could exist outside of Turing computability, or that Turing computability represents the ultimate limit of all formalization. He also insisted on concentrating on functioning concepts, as if only that which we can currently calculate could be real. In addition to Bach, there are a whole range of AI proponents and even more popular science authors who believe that the current computer metaphor for the brain is apt.

As shown, the qualitative differences in structure and parallelism between computer simulations and living systems are obvious. But living systems "work". I expressed my disappointment to Rudolf Kaehr and described to him my example of the relationship between the genome and proteome of a living cell and the dialog with Joscha Bach. He reacted with astonishment to my example, thought it was good, especially as an argument in discussions, and advised me to "keep at it".[33]

Further development of the example

However, I can no longer maintain the specific example in this form today. It requires at least one addition. First of all, I must add that the way in which the interactions between genome and proteome are described follows a structural model. This is a constituent sentence from second-order cybernetics, known after its originator as Heinz von Foerster's first proposition: "*The meaning of the signals of the sensorium are determined by the motorium; and the meaning of the signals of the motorium are determined by the sensorium.*"[34] The assumed circular operator-operand relationships between genome and proteome correspond here to the relationships between sensorium and motorium of a living system assumed by Foerster. In the first case, it is about the self-preservation of the system, in the second about the interaction of the system with its external world.

In very simplified terms, it can of course be said that the genome determines the proteome and, conversely, the proteome maintains the genome. From the point of view of the activity of a cell, however, it is merely - as Maturana and Varela put it - "*proteins, enzymatic and structural, which specifically participate in the production of proteins, nucleic acids, lipids, glucides and metabolites.*"[35] and thus permanently reproduce the cell with resources from the outside world. In this model, the genome essentially functions as a storage medium for amino acid sequences, i.e. for proteins.

The British physiologist and pioneer of systems biology Denis Noble interprets the genome as a collection of switches with codes for amino acid sequences for the production of certain proteins and explicitly not as a kind of program. "*What you've got is a series of switches, because it is true that each sequence that can be used to make an RNA a protein has a place where it can be switched on or off, sure. But that's the switch, it's not the if-then-logic, the logic is not there.*"[[36]] Noble thus clearly opposes the computer metaphor in genetics and thus also genetic determinism. This relatively recent view is also a harsh criticism of neo-Darwinism, whose proponents put the genome at the center of their considerations[[37]]

Two books, two contacts

At the end of 2023, Ulrich Kramer (formerly Autolab, FH Bielefeld) recommended the book by Jobst Landgrebe and Barry Smith, "*Why Machines Will Never Rule the World - Artificial Intelligence without Fear*" [[38]] to me on the occasion of one of my blog posts and, at my request, put me in touch with the author Jobst Landgrebe. The authors take a clear stance. They argue that an artificial intelligence that is equal to or superior to human intelligence, usually referred to as artificial general intelligence (AGI), is impossible for logical and mathematical reasons. Two main reasons are given for this assertion:

"*1. Human intelligence is a capability of a complex dynamic system - the human brain and central nervous system.*" and '*2. Systems of this sort cannot be modelled mathematically in a way that allows them to operate inside a computer.*'"[[39]]

Based on the first sentence and its focus on the central nervous system, one might get the idea that the authors represent a cerebrocentric view that indirectly supports the computer metaphor. However, they clearly oppose the neo-Cartesian position and speak throughout of the "*mind-body continuum*".[[40]] This identifies the authors as monists and staunch critics of transhumanist ideas such as uploading.[[41]] The two authors provide a logically and mathematically based, precise collection of what can and cannot be considered computable. They repeatedly refer to Alonzo Church and Alan Turing: "*That both symbolic and perceptron (neural network) logic are Turing-computable has been known to mathematicians and computer scientists since the 1950s, and this makes the whole debate look naïve at best.*"[[42]] They even devote a short chapter to the myth of hypercomputing, referring to the critical work of logician Martin Davis.[[43],[44]].

Jonathan Harth contacted me at the end of 2023; he and Werner Vogd had recently published a major work entitled "*Das Bewusstsein der Maschinen - die Mechanik des Bewusstseins - Mit Gotthard Günther über die Zukunft menschlicher und künstlicher Intelligenz nachdenken*"[[45]]. A meeting then took place in April 2024. They also refer to Alan Turing and see one of his legacies in "*having shown that cognitive processes can be modeled in such a way that the syntactic level of symbols familiar to us is abandoned and it is sufficient for problem solving if computers process ones and zeros according to mathematical-logical rules.*"[[46]] However, taking Gotthard Günther's view of the world as a network of distributed subjectivities into account, Vogd and Harth mainly start from philosophical and sociological points of view. In doing so, they arrive at interpretations whose essence can certainly be brought into line with the conclusions of Landgrebe and Smith. As they write in the introduction: *"An artificial intelligence [...] will never be able to draw an objective picture of the interrelationships of the world. All the artificial intelligences that will participate more and more in our social and societal life in the future cannot help but ignore the fine-grained* *nature of the world and will therefore be subjective to a certain extent. They will not lead to an objective appropriation of the world, but will rather enrich our world through their idiosyncrasies."* [47]

Of course, a justification based on the Turing machine and computability could also be found here. But by using the phrase "*in a certain sense subjective*", the authors implicitly express that the large language models (*LLMs*) on which the chatbots are based are perceived and used by human individuals as communication partners, a linguistic tribute to a frequent practice of human interaction with these systems. In this context, the term "subjective" is to be understood relationally and not ontologically. It is certainly justifiable - as a purely relational term - if it refers to the perception of the machine by the human counterpart.

In the meantime, this has become a tradition that is lived but also worthy of criticism, which is reflected in the concept of the Turing test. The philosopher Daniel Martin Feige comments on this: For Alan Turing "*replaced the question of whether machines can think with the question of whether we can recognize the difference between the text output of a human and a machine.*"[48] However, this means that a question that was previously unanswerable in terms of formal exactitude - such as, what is thinking? - has been replaced by an answerable one. A strategy that also has parallels in the realm of exact mathematics and logic.

Ultimately - at least so far - every new technology has led to learning processes and to the expansion and/or modification of our human capabilities. Vogd and Harth are counting on this when they write: "*Over time, we humans will learn to see through the mechanisms of our own mental processes more and more. We will be able to see how linguistically capable artificial intelligence can externalize our thinking in order to understand and break down the routines and institutionalized forms of our thought processes. We will learn to perceive and understand the fundamental limits of calculability (and thus of causal thinking) - for example by realizing that even the predictions of the most elaborate and fastest electronic brains can turn out to be wrong.*"[49]

This also contains a moment of dis-appointment - here with Heidegger's Ge-stell hyphen - the experience of the limits of the machine. Up to now, we have looked with joy and/or horror at the outputs of large language models, image generators and music AIs. But beyond our spontaneous amazement, it is time to ask ourselves what the outputs tell us about the patterns in our cultural assets, in text, image and sound media that were used to train the artificial neural networks: "*Machine learning is based on forming statistical correlations by means of multidimensional comparisons of feature combinations in order to derive patterns from them.*"[50]

Vogd and Harth also see Gotthard Günther's work *Das Bewußtsein der Maschinen* as "*a subtle criticism of the technical mania for feasibility. It is true that people will increasingly be able to build cognitive machines in their own image.*" But according to the authors, Günther in particular makes it clear "*that no (artificial) intelligence, no matter how elaborate, will ever be able to assume a divine position from which the conditions of the world could be objectively controlled.*"[51]

As with Landgrebe and Smith, this is a clear rejection of any idea of a singularity and, even more, of a superintelligence.[52] In my opinion, a comparison of the two works would not do them justice. For me, the statements of the two pairs of authors are entirely compatible with each other, they do not produce any major contradictions, and that despite the different ways in which they are justified.

However, I have to doubt whether Landgrebe and Smith would agree with this view, because they are both working in the realm of positive language, whereas Vogd and Harth use terms and attributions that can easily be interpreted as anthropomorphisms if not thought of dialectically.

Irreducible parallelism, a correction

I gratefully took the opportunity to discuss the topic of artificial intelligence, the authors' works and my own ideas on the subject in a telephone call with Jobst Landgrebe and a meeting with Werner Vogd and Jonathan Harth in spring 2024. There was a clearly positive response from all three authors to my example from biology and the concept of irreducible parallelism derived from it. Here, irreducible parallelism refers to a fundamental property of the processuality of biology that cannot be mapped to algorithms or the serially operating Turing machine, although it should be noted that sub-processes in biological systems can certainly be represented serially. I was able to argue and clarify the concept as a general core characteristic of complex interrelationships and, in particular, of complex life processes. All three authors asked me whether I was the author of this term, which I answered in the affirmative, and whether anything had been published on the subject, which I denied.

Today I have to apologize, because both answers are wrong. This came to light a few months later through research when I was writing another text. The fact that I had mentioned the impossibility of an *irreducible representation of simultaneity and parallelism* [53] in my 2014 publication, including the example from biology, had long since slipped my mind at the time of the discussions, as had the fact that I had already mentioned the term in similar contexts in another publication. [54] Obviously, my focus at the time in connection with thinking about complex systems was on other attributions and concepts. Only in recent years has the term gradually come to the fore as a summarizing core characteristic of complex systems, as their non-mappability to serial processes such as the Turing machine.

Where there is one error, there can be others. In this respect, the question of authorship is an implicit research task. As it turns out, the specific example and its use in this context can be traced back to my authorship, but not the term itself.

AI research on irreducible parallelism

The AI perplexity.ai is based on the GPT-3.5 language model from OpenAI and its own large language model (LLM) with integrated computational linguistics capabilities. The Pro version has access to GPT-4, Claude and its own experimental model.[55] Two reasoning models were recently added for the Pro version, o3-mini from OpenAI and a clone of the Chinese model DeepSeek R1, which is hosted in the USA.[56] The AI was the first publicly accessible system to have the advantage of explicitly specifying the URLs of sources from the Internet for verification purposes.

A recent search with the simple prompt "What is irreducible parallelism?" resulted in the statement "*The term 'irreducible parallelism' is not clearly defined in mathematics*", followed by an addition that the terms *irreducibility* and *parallelism* should be considered separately to explain the two concepts.[57] In addition, there was a list of exclusively mathematical statements with definitional character of the type "*An element of a ring is said to be irreducible if ...*", "*an irreducible topological space ...*", "*in geometry parallelism denotes ...*", etc. The simple query concludes with a speculation titled context: "*Although 'irreducible parallelism' is not an established mathematical* *term, one could speculate that it could refer to a fundamental, irreducible form of parallelism. This could be relevant, for example, in certain geometric structures or algebraic systems where parallelism is a fundamental, irreducible property.*"[58] The answer is conclusive. It was followed once again by a reference to the fact that the two concepts are normally separate in mathematics.

The same prompt addressed to the Pro version of perplexity.ai delivers basically identical, albeit more detailed statements and an intriguing speculative section divided into three parts:

"If we combine these concepts, "irreducible concurrency" could mean the following:

1. *Fundamental simultaneity: a state or process in which multiple elements or processes occur simultaneously without being able to be further decomposed into sequential or hierarchical structures.*
2. *Inseparable coexistence: Parallel systems or processes that are so closely interwoven that they cannot be separated or reduced to simpler components without losing their essential properties.*
3. *Emergent parallelism: A phenomenon in which the parallel structure or function is a fundamental property of the system and cannot be reduced to the properties of its individual parts.*"[59]

The system provided three more quite useful combinations of terms plus their definitions. This is a really respectable answer. The source wikipedia is very frequently represented in the answers.

A simple index-based Google search carried out some time ago with the search string "*irreduzible Parallelität*" only returned links to two of my own text productions, even in a recent repetition. Only when I entered "*irreducible parallelism*" in English did numerous links to a single new context come to light. This is a special term from a branch of linguistics, from so-called phonology, which was discussed by the phonologist John J. McCarthy, among others[60].

The pro version perplexity.ai does not even find this information if you ask the question in English: "*What is meant by irreducible parallelism?*" This is certainly due to the fact that the training dataset did not contain any more specific phonology texts.

Peter Molzberger: Computer science, self-organization, thinking and irreducible parallelism

An additional 2024 full-text search for "Irreduzible Parallelität" through my own digital archive returned the PDF version of a book that I had obtained in 2017 on the occasion of the creation of the digital archive of Rudolf Kaehr (1942-2016). It is volume 304 of the series "Informatik-Fachberichte" published by W. Brauer on behalf of the Gesellschaft für Informatik (GI). The volume, edited by Wolfgang Niegel and Peter Molzberger, "*Aspekte der Selbstorganisation*" (*Aspects of Self-Organization*) summarizes the contributions to a lecture series held at the University of the Federal Armed Forces in Munich in spring 1989 on this very topic of "*Self-Organization*".[61]

In addition to contributions by scientists from a wide range of disciplines and the essay by Kaehr "*Vom 'Selbst' in der Selbstorganisation* -"[62] *it contains a text by Molzberger, "Ist es sinnvoll, dass Informatiker das Phänomen Selbstorganisation behandeln?*"[63], which unfortunately had previously escaped my attention. In it, Molzberger describes his changing doubts and convictions regarding the expected performance of AI systems and comes to the following conclusion for himself: "*We have become so accustomed to the sequentializability of parallelism* ", meaning here of course the work of Rumelhart, McClelland and others*, "that any thought that this could encounter difficulties anywhere seems absurd. However, computer scientists were not the first to start thinking this way. Sequential thinking, thinking with our left brain, dominates our entire culture. It is difficult for me to find an example of "irreducible, i.e. non-sequentializable parallelism* ". *Our language is already designed in such a way that we cannot express such a thing. This makes it difficult, if not impossible, to present a proof for my thesis, because proof is always only possible within a closed and secure context. Irreducible parallelism, if it exists, is obviously something that goes beyond the current scientific context, the current paradigm.*"[64]

This is the oldest publication in which I was able to find '*irreduzible Parallelität*' as a fixed term, i.e. as an adjective and noun standing directly next to each other.

In terms of context, it should be mentioned that Molzberger's essay and the entire volume focus on the concept of self-organization, a collective term that has emerged since around the beginning of the 1960s [65], which encompasses a wide variety of qualitatively different processes of spontaneous structure formation occurring in inanimate and animate nature and whose popularity is largely due to the work of the physical chemist and Nobel Prize winner Ilya Prigogine.[66]. For the classification of the processes, please refer to the relevant literature.[67,68] In modern times, however, the use of the term can be "*traced back at least as far as Kant, who in the 'Critique of Judgment' of 1790 dealt with the internal expediency in nature, i.e. its systemic properties.*"[69,70]

Molzberger leaps associatively far - perhaps too far - in his article when he gives thinking the attribute sequential, immediately locating it anatomically as dominant in our culture and as "*thinking with our left brain hemisphere*".

Firstly, even today there is still no clear insistence on a separation between thought content and thought process, because "*thought content always forms a sequence of thoughts - in contrast to the thought process, which cannot be depicted sequentially, i.e. in a sequence of states, and is therefore in principle not directly accessible to human perception.*"[71] The latter can be demonstrated using fMRI methods [72] and can be easily inferred from the generally highly distributed neurophysiological activities of the neocortex. According to Eberhard von Goldammer, a distinction must therefore be made between the two.[73]

Secondly, Molzberger's statement is based on a fact that has been known since the late 1950s. From studies on the performance of the individual brain hemispheres using the so-called Wada test and on split-brain patients, we know that language comprehension and the ability to speak actively can be located unilaterally in the left hemisphere of the brain in almost all people.[74] However, thinking in the right hemisphere of the brain does not necessarily have to be different. It has been shown that the right hemisphere is significantly better and faster at recognizing patterns such as faces and in visual-spatial orientation. This is generally associated with a more 'holistic' perception of the world. However, this does not mean that in so-called 'thinking in pictures' the thought content cannot also form sequences.

What Molzberger is essentially alluding to, however, is the sequentiality of spoken and written language, or, to put it another way, the sequentiality of thought content externalized in speech and writing, with the help of which the connections labelled with irreducible parallelism in the aforementioned self-organizing systems can be described as such, but cannot be described. Thinking in language does not help us there and we encounter problems in describing processuality in biological systems.

Sequentiality(s), a search for traces

One possible starting point could be an attempt to shed light on the emergence of language and writing, i.e. the question of how such sequential sign systems came about in the evolution of mankind, which today form the basis and medium of our scientific work and have also been inscribed both in the theoretical concept of the Turing machine and in the engineering - i.e. the so-called von Neumann architecture - construction of computers.

In his work of linguistic analysis 'Grammatology', Jacques Derrida offers a new perspective on seriality and linearity in languages. According to the philosopher, *"the "line" represents only a particular model, whatever might be its privilege. This model has become [i] a model and, as a model, it remains inaccessible however privileged, represents only a particular model, a model that has become a model and as such remains inaccessible."*[75] Given that "*the linearity of language entails this vulgar and mundane concept of temporality [...],*" he argues that "*tthe meditation upon writing and the deconstruction of the history of philosophy become inseparable."*[76]

Regarding the line and its special relationship to knowledge and the cognitive, Derrida then arrives at the following statement: "*The enigmatic model of the line [ii] is thus the very thing that philosophy could not see when it had its eyes open on the interior of its own history. This night begins to lighten a little at the moment when linearity-which is not loss or absence but the repression of pluri-dimensional symbolic thought-relaxes its oppression because it begins to sterilize the technical and scientific economy that it has long favored*".[77]

Derrida's reference to the philosophical inability to see one's own history is at the same time a reference to the impossibility of seeing the line from a single point. A sensual clue here is that a graphic line is only visible when it can be perceived optically in contrast in front of or on the background of a surface. He then speaks of the repression of "*multidimensional symbolic thought*" and explicitly not of a loss. This implies that we still possess this ability, that it has only been covered over or repressed.

It must be emphasized that Derrida's arguments are based on empirical evidence; he refers repeatedly and in great detail to the meticulous research of archaeologist and anthropologist André Leroi-Gourhan. Leroi-Gourhan, who is primarily a paleoanthropologist, writes of a "*constriction of thought*". He sees the process of transition from what he calls mythological thinking to rational thinking "*in a very gradual shift exactly synchronous*" with the evolution of the city and metallurgy, and this in a period of about three millennia in the geographical area between Mesopotamia and ancient Greece.[78]

Nevertheless, the graphic, two-dimensional and spatial expression remains, to a certain extent "t*his mode has resisted the emergence of writing",* and at the same time *"exerted considerable influence*" upon it. Leroi-Gourhan further states that "*it still prevails in the sciences, where the linearization of*

i The word 'has become', 'devenu', is emphasized in italics in the original French and in all translations.
ii 'Line', 'ligne' emphasis likewise.

writing is actually an impediment". In his opinion it "provides algebraic equations or formulas in organic chemistry with the means of escaping from the constraint of one-dimensionality through figures in which phonetization is employed only as a commentary and the symbolic assemblage "speaks" for itself.[iii][79]

Leroi-Gourhan shows the linearization of thought as a bundle of processes that occurred in parallel and interwoven with the processes of the development and production of writing. This can be interpreted as follows. The overcoming of what he calls the *compulsion to one-dimensionality* by *figures* in the modern scientific media corresponds to the *loosening of the suppression through linearity* in Derrida, or the beginning of the *sterilization* of the *technical and scientific economy* that has so far been *favored by linearity*. In turn, Leroi-Gourhan's *figures refer to* the idea of the technopicture in Vilém Flusser's media and cultural theory.[80] Even if no references or quotations can be found in Flusser's work, it may be assumed that Leroi-Gourhan's work had a great influence on his thinking.

Irreduzibles, ireducible, an extended search for clues

Since the search for the string "irreduzible Parallelität" only found Molzberger's essay, the question arose as to what other terms could be found in the attribution space of the irreducible. A search for "irreduzi" limited to my own archive, in order to find the forms "irreduzibel" and "irreduzible" in addition to the noun "irreduzibilität", provided a few sources.

In the introductory words of the first chapter, "*Die Komplexität des Materiellen und das Versagen der Sprache*" of her dissertation "*Zählen und Erzählen*" the philosopher and feminist Eva Meyer points out that there is "*a growing awareness of the limits of language and its notation systems"*. She sees philosophy, logic and semiotics affected by this.[*81*]

The subtitle of Meyer's dissertation also has the character of a plea: "*For a Semiotics of the Feminine*." In line with this, and at the same time going beyond it, the author's aim is "*to initiate an expansion of what is conceptually possible*."[82] Therefore, "*the arena of a thinking that is not yet and no longer grounded must be opened up in order to open up the possibility of other relational structures.*"

The title of her work already makes it etymologically explicit that counting and telling have a common root and implicit in both is their structural property, the line form, linearity. In West Germanic languages, the English verb "*to tell*" is derived from the Old English "*tellan*", equivalent to calculating, Old Germanic "*taljanan*"; related to German "*zählen*" and "*erzählen*".[83]

The author finds what she is looking for in ancient Greece, where the long road to the dominance of linearity comes to a kind of conclusion in the transition from the Pythagorean conception of number to the Aristotelian one. "*The Pythagorean definition of number in its substance is not limited to the specifically Aristotelian meaning of substance [...]*"[84], but it also contains further meanings, those of matter and of property. "*The Pythagorean definition thus precedes the splitting of the concepts into form and matter and property.*"[85]

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iii "speaks", "parle", in the original French emphasized by quotation marks

Plato cultivates the Pythagorean conception of numbers, and in a report by Aristotle, there is talk of the *number of ideas*, the *mathematical number* and the *sensory number* in Plato.[[86]] For us, this only becomes understandable when we realize that, according to ancient Greek thought, mathematicians calculate with pure numbers and merchants and farmers use applied, or, if you will, bookkeeping numbers when counting goods and livestock.[[87]] This is what is meant by the number of senses; the farmer uses his senses to count cattle, etc. The number is determined by the senses, as in a herd the number of animals, and thus belongs to a certain extent to the concept. In addition, there is the idea of the number, which culminates in Plato's *indefinite duality (aoristos dyas)*. The character of the Pythagorean concept of number is immediately apparent in the first number, because "*the one represents both the limit and the infinite according to the Pythagorean teaching*"[[88]], so it is ambiguous.

Today, we are used to our natural numbers having only one predecessor and one successor, in accordance with Peano's axioms. However, this is not at all self-evident if we assume that the concept of one is already ambiguous. Plato himself worked with the Pythagorean concept of number, "assumed a multi-linear sequence of numbers and tried to develop it." Aristotle, as Gotthard Günther tells us, met this attempt in Book M of his Metaphysics with a criticism that was devastating for the time[[89]]

Aristotle thus virtually spoke out in favor of a ban, a ban on letting numbers dance out of line.

In "*compact conciseness*"[[90]], according to Joachim Castella, Eva Meyer explains the idea of multilinearity, of polylinearity, in a footnote, which is why his assessment is followed here and the quote is also reproduced in full: *"With 'multilinearity', a number-theoretical conception is addressed that does not go back to the contemporary theories of multilinearity, such as those known as recursive word arithmetic from mathematical linguistics. For while these can be mapped onto the linearity of natural numbers through Gödelization, the latter is a primary, <u>irreducible</u> [[iv]] conception of multilinearity. A geometric figure, as illustrated by the line, but also by the circle and the spiral, each of which is also only a model of the line, is not sufficient. For the circle, which describes a homogeneous field, and the spiral, which unrolls its telos from its origin, remain subject to the principle of identity through the unambiguousness of their construction and definition. For an inherently contradictory or dialectical conception, however, not only one figure is required, but a variety of figures. Its simplest model is multilinearity.*"[[91]]

The simplest possible model of a multiplicity of figures is multilinearity. Meyer continues in her footnote: "*Only now can the effectiveness of the concept of linearization be understood. In order to regain access to the completely different structure of multilinearity, a fundamental problematization of the concept of symbol and language is required.*"[[92]] To this end, she takes up a suggestion by Derrida to combine the process of linearization described by Leroi-Gourhan with Jakobson's critique of Saussure's linearist concept of language. This is followed by Derrida's above-mentioned quote from Grammatology: *"The "line" represents only a particular model, whatever might be its privilege. This model has become a model and, as a model, it remains inaccessible however privileged, represents only a particular model, a model that has become a model and as such remains inaccessible."*[[93]]

iv Hervorhebung J. Paul

At the end of her footnote, Meyer names the prerequisite for the accessibility of the model that has become processual: *"The accessibility of the model of the line as something that has become can therefore only be realized under the assumption of a repressed* <u>*irreducible*</u> *[v] otherness - a primary (Pythagorean) multilinearity.*"[94]

The attribution *irreduzibel* is found here once for the conception of multilinearity as well as for otherness.

Lost property, other irreducible qualities

One task can now be to work out this repressed irreducible otherness. In a work by Rudolf Kaehr, there is a whole collection of terms lined up behind the adjective: "*Every attempt to introduce* <u>*irreducible*</u> *[vi] multiplicity, ambiguity, parallelism and cooperationat a basal level fails due to this fundamental unambiguity of formalisms. Multiple structures and processes can only be defined as derived theoretical constructs, but not as basic structures of formalisms."*[95]

Kaehr refers here to the demand for uniqueness and identity of signs in mathematical writing systems, which, as we know, goes back in principle to Aristotle, who criticized in particular the Pythagorean concept of the number of ideas, which was also used by Plato. Plato only accepted ideas from the first ten numbers, but not from all the others. For the Pythagoreans, 10 is a sacred number, as it is equal to the sum of the tetraktys, the fourness of the numbers from 1 to 4. For Aristotle, the idea of the number 10 does not result from the sum of the ideas for the 8 and the 2, for example; the numbers of ideas cannot be generated by arithmetical operations.[96] "*It is necessary to be consistent* ".[97] Gotthard Günther largely agrees with Aristotle, for one cannot grant the numbers from 1 to 10 the rank of an ontological ideality, but not all others.[98] It is well known that Gotthard Günther ultimately decided, through the development of his theory of dialectical numbers, to grant each number "*the dignity of an idea*"[99]. Kaehr concedes, however, that this allows for "*the less dialectical moment of bad infinity*".[100]

But Aristotle marks a turning point. Here a definitive conceptual separation of number and concept occurs. It follows directly from this that it is now impossible to calculate with concepts. We are dealing with a fundamental conflict between conceptuality and calculability. In a 1994 article, Kaehr concludes that "*as long as the gap between concept and number is not bridged, [...] the visions of artificial intelligence [...] as intended by AI*" research"*[...] and artificial life research remain unrealizable in principle.*"[101]

For the majority of AI scientists active today, this is a huge provocation. Because even programmers themselves are now saying that machine learning systems such as artificial neural networks not only copy intelligence, but are intelligent. "*It transforms you when you program.*"[102]

Nevertheless, Kaehr's conclusion raises the all too justified question of how the current large language models, the LLMs, can come up with answer texts that can be described as quite meaningful. We remember that the current hype really picked up speed again on November 30, 2022, when OpenAI released its GPT version 3 as the ChatGPT dialog system for public use worldwide, a construct with 175 billion parameters, almost impossible for a human mind to keep track of quantitatively. However, it quickly became clear that this system and, without exception, all

v Emphasis J. Paul
vi Emphasis J. Paul

of its successors, some of which are much larger, whether from OpenAI itself or from Google/ Alphabet, Facebook/Meta, Anthropic, etc., have considerable weaknesses when it comes to generating logical reasoning. It would be more accurate to say that they are weak in generating meaningful strings of words that can be interpreted as conclusive reasons. The great tinkering began in order to eliminate such errors through fine-tuning.

Obviously, stochastics, *stochastikē technē*, lat. *ars conjectandi*, the "*art of conjecturing*", can be approached with further sophisticated statistical procedures as well as fine-tuning and reinforcement learning in such a way that in most cases something meaningful and - as far as reasoning is concerned - correct emerges.[103] Anthropomorphizations related to the machines should therefore continue to give way to mathematical disillusionment.

Self-referentiality as an irreducible system property

The term "self-referentiality as an <u>*irreducible*</u> *[vii] property of a system"* appears in an essay by Joseph Ditterich. [104] The author discusses the conditions and elements necessary for an operational foundation of self-referential systems under the title "*Contexturality: System Restructuring for Self-Reference*". As mentioned above, Maturana and Varela's concept of autopoiesis is not sufficient here, as it is a purely narrative description. We will return to the concept of contexture.

Self-referentiality is generally understood as something that is related to itself or that refers to itself. The term has a broad meaning. In addition to the narrow, logical meaning, e.g. for sentences that refer to themselves, system-theoretical and biological meanings of the term are also interesting for the discussion here. In order for a biological system, e.g. a cell, to be able to metabolize, grow and reproduce, it must be able to have a relationship to itself, generally speaking. It is quite easy to see that the living system must therefore be able to draw and manipulate a distinction between itself and its system environment so that, firstly, it can maintain and reproduce itself instead of producing something and, secondly, so that it does not digest itself, so to speak. The system therefore requires a "*conception for the interplay of open and closed states*" [105] of the system, i.e. of itself.

But where does this ability of the living system come from? With Rudolf Kaehr we can ask: "*Is it not rather the case that the being-in-the-world of living systems is self-referentially structured in itself, that it is not parts of the system, but the system itself, the living system, that constitutes self-referentiality?*"[106] He emphasizes that "*self-referentiality proves ever more clearly to be a basic structure of matter*", referring to works by Manfred Eigen, Edgar Morin and Ernst Jantsch.[107,108] *According to one view, "the phenomenon of self-referentiality [...] brings together the fundamental problems of almost all sciences."*[109] Following Ilya Prigogine, it can be said that self-reference is a state of affairs that *is* not, but *becomes*.[110,111]

The question now arises as to how self-referentiality and the aforementioned concept of self-organization are connected. "*The self-organization of a system is a form of organization in which structural self-referentiality is necessary to realize the self-organization of the system.*"[112] In order to describe the self-organization of complex systems, a structural theory is required that can represent the interaction of relations and processes, and that can do so for several relations and processes at a time. For the various components of this structure, their sub-objects or sub-systems, this means that their categorical identities change fundamentally when the relation changes. For

vii Emphasis J. Paul

example, an operator becomes an operand, an operand becomes an operator. Or, to put it another way, the parallel functioning of the structural components in several relations and processes means that they can no longer have a fixed identity. They can function as complex objects, as structural components of complex systems in the various relations in parallel and 'together' [viii] in their various structural determinations and change their determinations from their various structural contexts. The complexity of the individual objects results from their self-referentially differentiated structural functions within the framework of the self-organization of their complex system. Their complexity depends on the number of relations in which they function as structural components, i.e. not all have the same structural complexity. For a simple protein A, the situation may be that it is currently being produced by means of protein biosynthesis and at other sites it is fulfilling one or more enzymatic or structural tasks. This applies analogously to further sub-objects or sub-systems. [113]

In other words, in complex systems, a reversal of the above-mentioned categories of operator and operand takes place at the points where relations and processes are linked when the relation changes. Gotthard Günther determines this linking processuality by means of the so-called proemial relation, which can be represented as the change of precisely those basic categories.[114]

The linguistic effort to get the interrelations within a cell onto the - causal - chain can be clearly seen here. That is, the above-mentioned model of the line fails completely, and not only when attempting linguistic linearization. The same applies to formalization. A calculus for self-referentiality on the basis of classical mathematics and logic proves to be impossible, which is why Rudolf Kaehr argues for a self-referential calculus.[115] However, this requires an extension of the classical formalization methods.

Calculability and its limits

The mathematician Engelbert Kronthaler's approach to linearity and unambiguity in mathematics can be seen as entirely analogous to the history of argumentation from Leroi-Gourhan to Derrida to Eva Meyer, who sought to make the line accessible as something that has become against the background of an otherness. In his metamathematical [ix] work *Grundlegung einer Mathematik der Qualitäten,* he says of the limit theorems: *"It would be presumptuous to doubt their results, especially the limit theorems of Gödel, Church ... on the contrary: only the conclusion of these theories by such limit theorems requires/enables [x] their extension."* This is undoubtedly the statement of a dialectician. He continues: *"But this extension is no longer possible - precisely because of these propositions - within the classical if-then framework."*[116] This if, the premise, must be extended, but *"the presuppositions of the A-formalisms [xi] must be reflected upon, which has so far been prevented by a taboo. This taboo"* ensures *"the claim to absoluteness of A-logic and -mathematics and thus"* leads to *"an absolutization of their limit theorems."*[117] However, if the preconditions are now also considered, or if the if-then is understood as a whole, then, according to the mathematician, many problems would turn out to be illusory problems.[118]

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viii In German, the word 'zugleich' was used, which does not express exactly the same thing as 'gleichzeitig'. Therefore, the word 'together' was chosen for the translation.

ix Metamathematics is the study of the foundations of mathematics.

x requires/enables is superimposed in the original, in a sense of a switch in the sentence, where the text first diverges and then converges again. In his work, Kronthaler often uses this open-endedness of linearity as a stylistic device to point out the limits of linearity.

xi Note: The 'A-' prefix stands for Aristotle, or the Aristotelian concept of logic and mathematics.

He therefore advises changing one's point of view by looking at the problem and its premises from the outside, so to speak, instead of restricting one's thinking to the interior of the problem from the outset. To substantiate the possible success of such an approach, he cites examples from mathematics and logic, Euclid's parallel axiom, the continuum hypothesis and the axiom of choice.

In several places in Kronthaler's and Kaehr's works, a sentence fragment is quoted from a footnote by the Polish-American mathematician and logician Emil Post, who thus gives a name to the above-mentioned taboo. He speaks with regard to the limit theorems of Gödel and Church in particular: *"But to mask this identification under a definition hides the fact that a fundamental discovery in the <u>limitations of the mathematicizing power of Homo Sapiens</u> [xii] has been made and blinds us to the need of its continual verification.*"[119]

What is not clear from the sentence fragment quoted by Kronthaler and Kaehr is that Post is specifically referring to a work by Church [120] and is objecting to a hasty absolutization of the limit theorems. He criticizes the concealment of a fundamental discovery about the limits of our mathematical abilities under a definition, which makes us blind to the necessity of their continuous review.

Kronthaler interprets this taboo merely as "the *limit of a game of signs, the if-then game of A-mathematics.*" The non-inclusion of the if-premise is all the more surprising, since the questioning of premises has repeatedly led to success in individual cases – even if only with great difficulty, as in the development of Euclidean geometry into topology.[121]

Furthermore, I would like to emphasize that Kronthaler's expression of the game of signs also implicitly leads back to the levels of argumentation of Derrida and Leroi-Gourhan. This is because mathematics and logic occur in signs. They are taken from a finite set of signs and put into a series, a sequence that has a beginning and an end.

Kronthaler's line of argumentation on the emergence of the taboo is of particular interest because he works out essential details of an epistemological process. First, Gödel's incompleteness theorems and their significance for the limits of computability in formal systems such as arithmetic are discussed. It is shown that such systems cannot prove their own consistency. For the case treated in Kronthaler's work, the border area between mathematics, logic and metamathematics, in addition to the "*impossibility theorems*" [122] by Gödel in 1931 and Church in 1936 [123] and their generalizations by Rosser [124] and Kleene [125] mark such a border. A further consolidation of the above-mentioned taboo was reinforced by additional sentences such as those of Löwenheim-Skolem, Frobenius and Pontrjagin. Kronthaler sees in this development a gradual absolutization of the claim of the A-concept, if you will, a freezing of the intellectual attitude towards formal systems. Furthermore, he calls on the mathematician Hans Hermes as an advocate of his argument from the taboo with a quote: "*Today it is generally believed that <u>every</u> system of algorithms can be defined by recursive functions, so that Gödel's result takes on a deeper meaning.*"[xiii,126] The chapter of historical consideration from his introduction to the theory of recursive functions, from which the above quote is taken, Hermes himself regards as heuristic.[127]

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xii Emphasis of the quoted sentence fragment by J. Paul

xiii Quote Hermes, emphasis by capital letters and exclamation marks (GLAUBT! en: believed) in the text of Kronthaler, every by Hermes, here the version of Hermes is reproduced.

Rudolf Kaehr's self-referential monsters

As for self-referentiality, Rudolf Kaehr even speaks of monsters and their exorcism, and advises reading the classics of mathematical basic research in terms of the imagery of burning witches. But contradictions are "*not errors or properties of an already defective system, but a correct system that, through the correct application of correct rules, leads to equally correct contradictions.*"[[128]] He points to the introductory words of Richard Howes and Heinz von Foerster to Francisco Varela's Calculus for Self-Reference, which turn this fact into a positive: "*Etymologically speaking, correct opinion is orthodox; paradox, however, lies beyond opinion. Unfortunately, orthodox attempts to establish the orthodoxy of the orthodox results in paradox, and, conversely, the appearance of paradox within the orthodox puts an end to the orthodoxy of the orthodox. In other words, paradox is the apostle of sedition in the kingdom of the orthodox.*"[[129]]

Orthodox attempts to establish the orthodoxy of the orthodox results lead to paradoxes, the appearance of which within orthodoxy puts an end to the orthodoxy of orthodoxy. Or to put it another way, the paradox is the apostle of the revolt in the realm of orthodoxy. And since what must not be must not be, such *seditious interventions* were long dismissed as *syntactic pathologies*, as *mental aberrations*, and their proponents as *cranks* or *semantic freaks*.[[130]] Kaehr sees a cultural context for society as a whole in the fact that the monster metaphor has been reappearing since around the 1970s and contradictions are now also cautiously being admitted in mathematics. It is no longer about exorcism but about domestication. A necessity arose from the preoccupation with the - so far purely narrative - theory of autopoietic systems. There could no longer be any doubt about the reality of self-referencing within the living cell and the structures of the connectome in nervous systems.

Multilinearity and multitemporality

The process conglomerate of a living cell - at several sites, several specific proteins are produced by means of protein synthesis; one of these is in turn involved in the "management" of the cell membrane, at a different site another is involved in the maintenance of the genome, yet another intervenes in the energy balance of the cell, which in turn exerts an influence on the production of certain proteins, etc. - can be interpreted to mean that each individual process has its own temporally modifiable rhythm that can be adapted to internal and/or external requirements. This results in an overall situation that Rudolf Kaehr has briefly described in another context. The cell as a whole no *longer behaves in accordance with discrete linear time sequences. There are several time sequences together.*" *The word 'together*' here explicitly does not mean '*in the sense of a superior time function, but <u>irreducibly parallel</u>.*[[xiv],[131]] The processes have their Eigen times and one can speak of a distribution of the time sequences, a temporal multilinearity that can no longer be mapped onto a scale of a reference time. This state of affairs is quite comparable, for example, to the already mentioned absence of a single clock in biological neuronal networks.

According to Kaehr, firstly, this means that the individual time sequences may or may not differ in structure, beat and chronology. To illustrate this, one can imagine a percussion ensemble playing polyrhythmically, with different entries and pauses, without a common score. In this example, the score would correspond to the non-existent reference time scale.

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xiv emphasis J. Paul

Secondly, "*what applies between the different times can no longer be gathered under the concerns of temporality*". This means that the distribution of time sequences does not happen again in a time sequence, i.e. in the sense of the non-existent score mentioned above. Kaehr speaks of a counter-rotation of time sequences. This can mean that "*a time sequence is oriented towards the system's future*", whereas a "*complementary time sequence can refer to the system's past*." Kaehr identifies terms such as *multi-temporality* and *counter-directionality* as "*first steps in a deconstruction of the linear concept of time towards an explication of temporalization and spatialization.*"[132]

Since about the 1980s, it has been widely discussed and expected that biology will become the leading science of the 21st century. In this rather science-historical sense, it can be understood that the life sciences will also influence our hitherto rather linear, classical physics-based everyday understanding of time.

The above has significant consequences for the state space [xv] of a biological system. If the time sequences of the individual processes can no longer be related to a common time scale, then the state space can no longer be hierarchized, i.e. there is no distance measure, no metric in this space. This is tantamount to violating the triangle inequality.

Ultrametricity

In order to assign a metric to a space or state space, or to define such a space at all, it is necessary in principle to have distance measures between the points in the space for which the so-called triangle inequality applies.

$$d(A,B) + d(B,C) \geq d(A,C)$$

This relationship is immediately conceivable. It states that the sum of the distance between two points in space, A and B, and the distance from B to a further point in space, C, must always be greater than or equal to the distance between points A and C. If the special case of equality applies, i.e. if the sum of the distances between A and B and B and C is equal to the distance from A to C, then point B lies exactly on the line between A and C. The triangle has, as it were, 'collapsed in on itself'. From this it becomes clear that the triangle inequality must also apply to points on an axis, such as a time axis. This applies to metric spaces. The so-called ultrametricity condition is even stricter:

$$\max\ [d(A,B),d(B,C)] \geq d(A,C)$$

A distance that fulfills the ultrametric variant of the triangle inequality is called an ultrametric distance; a space that is equipped with an ultrametric distance is called an ultrametric space. The origin of this form of the triangle inequality lies in the work of Kurt Hensel (1861-1941) on number theory, in which he introduced the concept of p-adic numbers.[133] In very general and abbreviated terms, this formalizes countabilities and classes, i.e. hierarchies in spaces of natural and rational numbers, which go beyond the generally known and usual principle of ordering, the size of a number.[134,135]

The similarity between the triangle inequality and the transitivity law of classical logic is striking.

xv Note: The state space is generally understood to be the extension of the phase space by time.

$$(A \rightarrow B) \wedge (B \rightarrow C) \rightarrow (A \rightarrow C)$$

This relationship expresses the so-called transitivity law of classical logical implication, read (if A, then B) logically AND (if B, then C) it follows (if A, then C). Beyond their visual similarity, the ultrametricity condition and the transitivity law of classical logic both establish a hierarchy.

Outside of mathematics, the concept of ultrametricity was first introduced into taxonomy. In this context, the hierarchical classification trees of plants and animals are particularly noteworthy. Depending on the application, different ultrametric distances can be used. The distances between the objects can be given by the known lines of descent, but also by other criteria, such as quantifiable similarities of certain proteins.

In addition, the property of ultrametricity was not only used early on to describe degenerate physical state systems in the case of so-called spin glasses, but also in AI research to describe the states in artificial neural networks and for models of associative memory.[136,137] For further discussion, see the fundamental essay by Rammal, Toulouse and Virasoro, *Ultrametricity for Physicists*.[138]

From a cybernetic perspective, the algorithms of neural networks represent classical input/output systems with implemented feedback (backpropagation), which are organized ultrametrically.[139] In 1984, Jean-Paul Benzécri provided a rigorous proof of the relationship between indexed hierarchies and ultrametricity, which are particularly evident in the aforementioned taxonomic classification trees.[140] VFrom a logical point of view, the relationship is even closer, as ultrametricity directly corresponds to the transitivity law of classical logic.

So far, all neuromorphic models discussed in the literature lead to ultrametricity as the simplest possible non-trivial organization of states.[141] Consequently, as Kaehr and von Goldammer stated in their 1989 publication, all these networks represent hierarchically structured models. [142]. Also in recent publications, not the slightest doubt is expressed that even in very large language models, such as OpenAI's ChatGPT, ultrametricity reigns. The only question is not whether they can be compared to real neural networks, but rather whether a stochastic reduction can be applied to the models to a not-too-large practical number of order parameters: "*One big question is whether we will be able to elaborate a statistical physics of deep network which is based on a not-too-large number of order parameters that can be controlled statistically, as was done in spin glasses.*" This is linked to the intention of developing the theory of spin glasses to a next level.[143]

Open questions

With regard to the irreducible parallel phenomena discussed here, the following can now be stated. The irreducible parallelism underlying the facts of multilinearity and multitimeliness is equivalent to, or must be associated with, a violation of the ultrametricity condition. No hierarchy, neither metric nor ultrametric, can be established.

What does this mean for the project of formally describing basic process networks in cell biology or biological neuronal networks? As has been said, formalism has been bound to the linearity of characters since its beginnings in antiquity. So what about the possibilities of an operational foundation for systems that establish self-referentiality?

Only an artificial neural network motivated by physiological studies has been constructed - on paper, so to speak - which its author Warren McCulloch says eludes a classical formalization method because - due to its topology - it is not subordinate to the law of transitivity.[144] And Kaehr and von Goldammer have shown that Gotthard Günther's work, his polycontextural logic, provides a way to formalize and operationalize such network structures. However, this presupposes other computer architectures beyond the prevailing rigorous binarity.[145] Condensed approaches to Gotthard Günther's work [146] are provided by the article *Einübung in eine andere Lektüre* by Rudolf Kaehr and Joseph Ditterich and the essay *Polycontexturality Theory* by Eberhard von Goldammer. [147,148]

Another path may be provided by an increasingly important field of modern mathematics itself, topology. In a compendium entitled *Raumwissenschaften* (*Spatial Sciences)* published in 2009, mathematician Markus Banagl points out that there may be situations in which a "*topological intuition*" can contribute to the solution of a problem, but that "*in a formal sense*" a topological space is missing. The concept of topos was introduced by Alexander Grothendieck: [149] "*Die klassische axiomatische Untermauerung der Mathematik ist die Mengenlehre.* "*The classical axiomatic underpinning of mathematics is set theory. The category of sets forms a topos; however, there are also other topoi, and the mathematician is free to choose an exotic topos as a framework for his work. It may be interesting for constructivists that there are topoi in which the axiom of choice of set theory or the tertium non datur of logic does not apply.*" In addition, other topoi are possible, including point-free topologies that work with open sets as fundamental objects and their so-called lattices.[150]

Consider, for example, McCulloch's topological proposal. Mind you, according to Banagl, these topoi are considered "*exotic*", but are now permitted. An unconditional exorcism of such self-contradictory mathematical monsters (Kaehr) is now refrained from. This approach corresponds to Kronthaler's demand to co-reflect the premises of the rules of a system.

Proposals on the concept of irreducible parallelism

Irreducible parallelism seems to me to be a suitable criterion for the narrative description of complex systems. The term refers to their internal structure and moves on a more general level, since it frees us from the use of the adverb *simultaneously* and the misleading use of the adjectives *simultaneous*, *synchronous*, *simultaneous* and *instantaneous*. The adjective *instantaneous* in particular contains no reference to the spatio-temporal internal structure of a happening.

Suggested definitions:

If the processes that constitute a system are irreducibly parallel, i.e. if they elude a complete classical description in logic and mathematics, then this system is complex.

Irreducible parallelism is synonymous with a violation of the triangle inequality, the ultrametricity condition.

Eva Meyer: A system is called complex when it is no longer described from a single point of view, but from a multiplicity of complementary and mutually exclusive points of view that must be mediated with each other.[151]

Eberhard von Goldammer: A complex system is a system whose formal description criteria cannot be reduced to one contexture.[152]

Gotthard Günther: The term "*contexture*" refers to a logically bivalent structural area that is structurally limited by its bivalence, but whose content capacity and absorption capacity are unlimited.[153]

Joachim Paul: Complexity is understood to be a certain system property in which the elements of the system and their structures of action cannot be described by unambiguous operator-operand assignments that remain constant over time in the formal description of the system. Role changes occur corresponding to the order relations, exchange relations and identity relations in Günther's multi-digit logic systems. The system-internal processes are irreducibly parallel.

In this sense, today's AI systems are not complex.

In the positive-language sciences, it is common practice that the subject is expelled from the texts and statements. However, it is the subject that decides by force of its own will to describe a fact and, if necessary, to create a formal context for it.

In conclusion, I will therefore leave it to Gotthard Günther to describe the formalization process itself: "*But if we ask where the I takes the power to think from, we must say, as Fichte already knew, that the beginning of thinking is not that I think, but that It thinks in me. But where the id thinks in me, there I am not separated from the world and thinking is subject and object at the same time. But this is nothing other than dialectical thinking, which must therefore precede all formalization. From this, however, it follows that all formalization must fundamentally fall short of the structural richness of that which it formalizes. Although it is part of the power of dialectics that it can release formalizations of itself from itself, it also has the power to rush ahead of every formalization and to remain the unattainable goal of the formal logical process.*"[154]

With Sand Talk, Tyson Yunkaporta, a member of the Apalech clan and lecturer in Indigenous Knowledge at Deakin University in Melbourne, has created a topical philosophical-literary work as a bridge that can serve us as an approach to and exercise program for thinking that does not reflect the sequentiality of language and writing.[155]

This metaphorical bridge in the mental fog must be passable in both directions. The childhood story of the German writer Axel Brauns may serve as a further indication of the parallels and connections in the developments of writing and image, of the linear and the two-dimensional, the parallel, described so impressively by Leroi-Gourhan. He reported that - as a non-linguistically gifted autistic person - he learned language through geometric relationships between words and through counting. His parents ran a puzzle office for crossword puzzles. "*I became a writer because it has to do with stories, and there are layers in stories, and these layers are like the layers of sand on the beach, and grains can be told*", "er"-zählt in German".[156]

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