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Eternal, Data, Decay

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The theory proposed in this paper suggests that the pursuit of immortality is a significant motivator behind the development of digital data technologies. Data storage is viewed as eternal, as the information itself does not decay. Although the hardware that contains the data may decay, the information can remain immortal due to lossless duplication. This characteristic of digital technology provides significant advantages and is a key factor in the success of information technology. However, the idea of data as eternal creates social and natural fallacies based on a simplistic model of knowledge as storage. Memory is more than bytes on a silicon chip. Generalization, abstraction, and forgetting are key components of thinking. It is argued that a new concept and model of data will be necessary for a sustainable and socially responsible collective future.

1. Save for Later

Attending a concert in the 21st century can often be an unsettling experience. Instead of thoroughly enjoying and immersing themselves in the music, many people remain still, holding up smartphones to record the performance. This reduces the bodily experience to an unsteady tripod recording, which cannot capture the essence of the performance. It is not just concerts but all kinds of events where such behavior is becoming the norm. The 'save for later' approach is becoming standard (Tamir 2018). It is still being determined if anyone will ever watch those shaky videos with poor audio. In the 21st century, humans have willingly transformed into data-gathering devices, contributing to global-scale database structures. There is an inner urge to capture moments rather than experience them, which is not limited to mobile device cameras. Global web companies track every move of our mice and trackpads, including each scroll and pause (Wolfie et al. 2017). Data collection has become habitual (Chun 2016). Global web companies track every movement of our computer input devices, including mice, trackpads, and gestures. This includes tracking scrolling and pauses. Gathering data has become the lifestyle of the 21st century. This data is used to train machine learning algorithms mimicking our behavior. From image tagging and text translation to content generation, machines are made to behave in forms similar to the data gathered by/through us.

The urge to "save for later" to record the most mundane things is a fascinating question (Sparrow et al. 2011), but what interests this paper most is the discrepancy between the model of digital data and the world we inhabit. As any human reading this text knows, we are all getting older. At some point, wrinkles appear, hair grows thinner, exercise

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becomes more difficult, and memory fades. The same is true of every pair of shoes I have ever owned: traces of time are inevitable. Everything grows and decays: A tree sprouts leaves; they grow and wilt in the fall, starting a cycle of growth and decay again. The pre-digital photos of your childhood show the signs of time as the colors slowly desaturate and a faint, ever-increasing yellow haze develops. Over millions of years, pressure, temperature, and chemical reactions have transformed sand into stone. Nothing is permanent; everything is in flux, always.

However, data as transmittable and storable computer information (etymonline 2024) is not conceptualized in this way: Data has a binary concept of decay, i.e., it is or it is not, and the transition between these two states is almost non-existent. Data centers are like cold storage houses for fruit or old books, where the hardware slowly decays over time, but the content, the data, does not decay in the same way. The distinction between hardware and software, between the physical and the digital, or between the medium and the message conceptualizes data as immortal (Rothblatt 2014). While errors occur when DNA is copied from one cell to another, copying data from one storage device to another is error-free in most cases. The process of lossless copying allows computational data to be conceptualized as eternal. Or as written in the journal Science by Marcia McNutt, “data are forever” (2015). Its immortality may be why humanity is so attracted to it: the “later” in “save for later” is attached to the promise of eternity (Fawns 2011; Kurzweil 2024).

As your favorite musician ages, retires, or dies, the shaky video footage recorded on your cell phone and stored in a network of global data centers will continue to exist, unaffected by the mechanisms of aging to which everything else in the world is subject. Data survives death by making lossless copies of itself. Of course, this is not entirely true: codecs change, data is deleted, and storage devices break. Keeping computer data intact is hard work. But what makes data unique compared to everything else is that data does not decay. As long as I can open it and it is not deleted, a digital image will stay the same. It will not turn yellow; the colors will not slowly desaturate and fade. The software part of the dual hardware/software divide will remain as long as it exists. The binary underpinnings of computation also determine the concept of data storage — data either is or is not.

2. Fallacies of Data

One can easily argue that the conceptualization of digital data as immortal is one of the greatest advances: its lossless reproducibility and its capabilities as a non—decaying storage medium are vast improvements in a world where everything else will sooner or later succumb to the laws of entropy. —A world in which the characters in older Wikipedia articles would slowly fade, or web pages would turn yellow if not constantly updated is, after all, a strange thought experiment. But to some extent, this is happening: website links are constantly disappearing (Bowers 2021; Garber 2013), a phenomenon called link rot, and if I don’t constantly update my devices with the latest software, these systems will become unusable (Chun 2016). However, the mode at play here is different: code can be read by a system or not.

In the spring of 2022, a group of researchers at the ZKM (Center for Art and Media, Karlsruhe, Germany) attempted to restart one of the earliest computers, the Zuse Z22, with serial number 13. This computer, developed in 1957 by Konrad Zuse and chief designer Lorenz Hanewinkel, uses 415 vacuum tubes (ZKM 2024).; 65 years after its development, running the software on the hardware proved to be a laborious task. The difference that fascinates me is that once the software runs, it runs just as it did in 1957. While photographs from that time, stored on analog photographic paper, will show signs of decay, the software code remains unaffected by time. Computer systems are fragile. However, the underlying concept is different from that of decaying entities. In the next three sections, I want to explore three perspectives on why such a concept of data might be problematic. There are social, climatic, and conceptual reasons why it makes sense for everything in the world to be in flux. The concept of data as eternal, as a non-decaying entity, may not always be favorable.

2.1 Social Aspects

Over the past four decades, the Internet has undergone a profound transformation, evolving from its origins in military and research applications to become a pervasive global phenomenon that has shaped and continues to shape almost every aspect of human life (Castells et al. 2014). With its transition to a mass medium, storage capabilities and content changed dramatically. In particular, the emergence of large online platforms, credit reporting agencies, and consumer data brokers has given rise to companies with extensive knowledge about a large portion of the world's population (Wolfie et al. 2017). Some research suggests that social media companies can judge a user's personality better than close relatives or friends based on the data these companies collect (Youyou et al. 2015). Furthermore, advances in machine learning are leading to troubling new search engines that can find photos of a person based on a single image (Hill 2022). Often, as I have experienced myself, the results of such searches include images unknown to you. The scope and magnitude of the societal changes resulting from individual data collection cannot yet be fully grasped. We live in an era of gambling with the concept of privacy, and it is unclear who will win and who will lose in this game.

The European Union and countries like Argentina and the Philippines have introduced right-to-be-forgotten laws. These laws are intended to prevent stigmatization based on past actions (Mantelero 2013). However, these laws raise several issues and questions: One concern is where to draw the line between the right to be forgotten and freedom of speech (Solove 2003; Mayes 2011); the executive director of the Wikimedia Foundation, Lila Tretikov, has criticized the EU for punching holes in free knowledge (Tretikov 2014); another is technical implementation: Because digital data is so easy to copy, it is difficult to contain its spread. In sociology, this is known as the Streisand effect, meaning that the containment of information - in this case, an image of Barbra Streisand's Malibu home - has the unintended consequence of increasing awareness and, thus, spreading that very information. The difficulties of "digital forgetting" place a burden on individual victims, as illustrated in a 2019 New York Times article on online child abuse content (Keller et al. 2019): Digital images remain online forever, as long as they are duplicated and stored in various online locations. Even in the illegal case of child abuse content, the right to be forgotten seems impossible to enforce. Social media and cloud storage companies are caught between discovering these images and protecting the privacy of their customers. The digital notion of immortal data creates conflict and suffering on a social scale. The digital idea of lossless reproduction of information leads to a world in which specific actions that are destructive on a personal level are virtually perpetuated.

2.2 Ecological Aspects

The metaphor of the cloud in 'cloud computing' and 'cloud storage' is ill-defined: clouds of frozen or liquid droplets suspended in the atmosphere have little to do with the server systems that enable planetary-scale networked computing. While the floating water particles and resulting rain make life on Earth possible, cloud storage is becoming one of the planet's most energy-intensive and destructive industries. In 2007, the average data center consumed as much energy as 25,000 homes (Kaplan 2008). Over the past decade, this consumption has increased dramatically and shows no sign of slowing in the 2030s.

Similarly, the web metaphor draws on the image of almost invisible silk-based spider webs. The web metaphor suggests lightness, transparency, extraordinary stability, and a state of floating in the sky. By 2019, approximately 20 billion devices will be connected to the Internet. Predictions estimate a doubling from 20 to 40 billion devices by 2025 (Vailshery 2022). In 1987, traffic to and from data centers was about two terabytes, twice the size of the hard drive on which this text is written. By 2007, that number had grown 250 million times to 50 exabytes. 2017, that number reached 1.1 zettabytes (a 10 with 21 zeros). In 2017, data centers consumed an estimated 200 terawatt-hours per year or about 1% of the world's electricity. They contributed about 0.3% of total carbon emissions (Jones 2018), and these numbers are expected to double by the 2020s.

In 2018, a study by OpenAI predicted that the electricity needed to train state-of-the-art machine learning models would double every 3.4 months (Amodei & Hernandez 2018) and that training GPT-3, a deep learning model for producing human-like text, would consume an estimated 1,404 megawatt-hours in 2020. Cryptocurrencies, like artificial intelligence, are marketed as the latest technological innovations. However, these developments do not seem to consider that we need to take a fundamentally different path in the future. Cryptocurrencies are the latest technological development to promote the notion of data as immortal - the distributed ledger is the ultimate invention of not forgetting. Not only is every transaction stored on a blockchain, but every blockchain stores every transaction. Every connected system must hold the entire list of records called blocks. Removing, decaying, or forgetting would break the system.

Cryptocurrencies are conceptualized as an accumulation of data; decay is not only excluded but would break the system. In 2021, the energy consumption associated with cryptocurrency mining alone will consume approximately 120 terawatt-hours of electricity (ccaf.io 2024). According to a comparison by the BBC, the energy consumed by crypto mining could power all the electric kettles used in the UK for 27 years (Criddle 2021). Various calculations suggest that one Bitcoin transaction emits as much CO2 as an average household for three weeks (Whitehead 2022) or about the same as a business-class flight from Berlin to London (stackexchange.com 2019). The metaverse, the dream of an integrated network of 3D virtual worlds, is now following the crypto trend. The metaverse television series Upload is a perfect example of the dream of immortality through digital technology. The plot is simple: by 2033, people can "upload" themselves into a virtual afterlife. The metaverse is another step toward digital eternity: death lurks around every corner, and data is the 21st-century mechanism for dealing with it.

It might not be a pure coincidence that crypto, from Greek "kruptos," means hidden, as data, from Latin the given, its transformation and production are far from the metaphors describing them. The technological infrastructure puts a heavy burden on the planet. The tools to detect climate change in the first place, i.e., supercomputers and global sensing devices, are the tools that multiply the problem. Understanding and destruction amalgamate. However, the constant flux of growth and decay of the world we inhabit creates space for alternatives. The hoarding of the digital and its various trending terms only considers one side: growth, but not decay. Each new technological invention seems not only to continue on this path but to multiply it exponentially.

2.3 Conceptual Aspects

The argument I have presented so far challenges the concept of digital data as eternal. Digital data does not decay, it is or it is not. While such a concept makes sense concerning the origins of computing systems in military and research programs, it causes tremendous disruption on both social and environmental levels in the contemporary world. What if the model of eternal data is not only socially disruptive and environmentally questionable but also a conceptually flawed understanding of memory and knowledge?

In 1942, five years after the development of the first electromechanical computer (Dorsch 1989), Argentine author Jorge Luis Borges published a short story entitled "Funes el memorioso" (later published in English as "Funes, the Memorious"). It is a tale about a man, Ireneo Funes, who acquires the ability to remember everything after falling from a horse. In the short story, Funes is, for example, able to remember every shape of every cloud at every moment. However, Borges' story is not just fiction: several people with savant syndrome have abilities similar to those described by Borges. For example, Kim Peek (1951-2009) was able to name every city in the U.S.-almost 20,000 in all-including its zip code and area code, as well as the highway leading to each city. Among other things, he knew the contents of 12,000 books by heart (Weber 2009). These various abilities remind me of the digital systems in which we are embedded. An e-book reader or smartphone can easily store 12,000 books. A dataset of all U.S. cities, including various data dimensions, is less than 1 megabyte. Digital data has capabilities that hold similarities to those described above. But, as Borges writes, Funes's new ability came at a price: "He was, let us not forget, almost incapable of general, platonic ideas" (Borges 1942, 114).

The digital impulse of eternal data, of the human urge to "save for later," to record history to the fullest might replace the virtue of knowledge with masses of data. Planetary-scale networked computation is based on the principle of storing everything, but already Friedrich Nietzsche commented on the power of forgetting:

> *Imagine the most extreme example, a human being who does not possess the power to forget, who is damned to see becoming everywhere; such a human being would no longer believe in his own being, would no longer believe in himself, would see everything flow apart in turbulent particles, and would lose himself in this stream of becoming […]. All action requires forgetting, just as the existence of all organic things requires not only light, but darkness as well. (Nietzsche 1995)*

In "On the Utility and Liability of History for Life" (1874), Nietzsche describes too much history as a danger to life: Instead of focusing on experiencing the present, we are too busy focusing on how we are going to reflect on events once they have passed.[1] —Recording takes over living. The question of how one remembers eradicates the experience of the moment.

From a different perspective, Théodule Ribot writes in *Les maladies de la mémoir* (1881) that "the paradoxical result [is] that one condition of remembering is that we should forget. Without totally forgetting a prodigious number of states of consciousness and momentarily forgetting a large number, we could not remember at all" (James 1890). Human memory works fundamentally differently than computational data storage: In the human brain, sensory memories last only a fraction of a second. The things we devote our attention to become short-term memories lasting only a few seconds. The hippocampus plays a crucial role in abstracting the world, merging details into long-term memories of the past (Quiroga 2012). These successive layers of abstraction are missing from the conceptualization of digital data: data is not abstracted to synthesize concepts. As Borges writes: "To think is to forget a difference, to generalize, to abstract. In the overly replete world of Funes, there were nothing but details, almost contiguous details" (Borges 1942, 115) .

Forgetting and abstracting are two key components that digital storage has yet to grasp. While humans store sensory memories only for a fraction of a second, this level of gathering demonstrates the concept of how data storage works long term. Recently, I requested Google to send me a data dump of all the company's information about me. The dataset contained a vast list of my search history, spanning almost the last two decades. Google does not 'forget' it stores what I searched for on May 17, 2010, at 8:53 a.m. Data is not abstracted, forgotten, drawn together, synthesized or combined over time. Like Funes in Borges' story, data is conceptualized as a hoarding of details[2]. The natural and societal consequences of such a misconception of the differences between memory and data are vast.

In his book *Borges and Memory*, Rodrigo Quian Quiroga relates his studies in neurology to the story of Funes, as it coincided with his research findings. For Quiroga, thinking is only possible by generating meaning and concepts through abstraction and forgetting. These two factors are closely related since abstraction implies neglecting and forgetting details. Quiroga makes analogies to the technical apparatus we use to capture the world: "We do not process images in our brains as a camera does; on the contrary, we extract a meaning and leave aside a multitude of details" (Quiroga 2012, 192). Furthermore, Quiroga calls the reality of the 21st century a Funesian world in which we are con-

1. Nietzsche writes: "Before the war is even over, it has already been transformed into a hundred thousand pages of printed paper, it has already been served up as the latest delicacy to the exhausted palates of the history-hungry." Nietzsche, "On the Utility," X.

stantly bombarded with digital information, from social media and email to 24-hour news channels. The very design of how memory is conceptualized as data, as the ever-lasting, never-forgetting, lies at the core of this problem. Memory, for Quiroga, is a creative process: “To think is to forget differences, to generalize, to abstract” (Quiroga 2012, 117). Thus, remembering is not, like data, a form of endless repetition of the same but rather something in flux, an ever-changing interplay between context and meaning.

3. A New Kind of Datum

Ut nihil non iisdem verbis redderetur auditum. (Borges 1942, 111)[3]

Although digital decay is not extensively researched, it is not entirely unexplored. The topic is approached in various ways, resulting in intentional and unintentional decay. This section will present different approaches and suggest ways to conceptualize data decay further.

Lossy compression refers to a collection of methods to decrease data size utilizing imprecise approximations and discarding partial data. These formats became popular during the early days of the Internet when bandwidth was limited. Examples of well-known formats include the image format JPEG, the audio format mp3, and various MPEG video formats. The technique used for lossy compression is called *discrete cosine transform* (DCT)[4]. In JPEG images, blocks of eight-by-eight pixels are transformed into a cosine wave function, requiring less storage than the original pixel blocks. However, if a file is compressed to a high degree, the wave functions become visible within the image. It is important to note that lossy compression affects each new copy of the data, meaning that a JPEG saved repeatedly will lose information over time. However, it is essential to note that this compression method was not intended to forget, simplify, or summarize. Its purpose was to facilitate faster file transfers over the slow internet of the 1990s.

While file compression functions on the data level of digital files, various apps with data self-destruction capabilities have been released over the past years. Gmail, for example, has the ability to send emails in a confidential mode (google 2024). This allows users to set an expiration date on their emails. Similarly, the messenger app Telegram allows for self-destructing messages (telegram 2022). When Snapchat was first launched, the app became known for its disappearing photos and videos. These examples demonstrate that digital ephemerality is not unthinkable. However, the systems are all based on a binary concept of forgetting. There is, again, no level of generalization or abstraction.

Rather than following the hype around cryptocurrencies in which remembering every transaction is a crucial system component, cryptography can also be used in reverse, i.e., to forget. The project *Vanish* by the University of Washington is an example of this: the system makes data unreadable after a user-specified period; the result is self-destructing data (Roxana et al. 2011). In 2007, Viktor Mayer-Schönberger made a similar argument about self-deleting data from a legal perspective (Mayer-Schoenberger 2007). However, the examples observed thus far are all based on deletion as the only mechanism of forgetting. Research in artificial neural networks might allow novel conceptualizations of digital memory that include generalization and abstraction. These techniques are inspired by biological neural networks that constitute

2. It should be noted that the analysis presented in this paper is somewhat ambiguous. While critiquing contemporary metaphors of computation, I am utilizing the same mechanism to draw a relation between Funes, a human character, and computational storage. However, this paper does not focus on the usage of metaphors per se, but rather on a reimagination of data beyond the binary imagination of existence.

3. Here, Borges quotes from Pliny’s Historia naturalis: “Nothing that has been heard can be repeated with the same words” (my translation). First published in 1942 as “Funes el memorioso,” the following translation of Borges’s short story is referred to in this text: Jorge Luis Borges, “Funes, the Memorious,” trans. Anthony Kerrigan, in Ficciones, ed. Anthony Kerrigan (New York: Grove Press, 1962), 107–115 (quotation on 111).

4. For a simple and valid explanation of the process see Computerphile, "JPEG DCT, Discrete Cosine Transform (JPEG Pt2)," *YouTube*, May 22, 2015, https://www.youtube.com/watch?v=Q2aEzeMDHMA.

animal brains, and movements toward abstraction are built into these systems (Saitta & Zucker 2013; Abel 2022). Each hidden convolutional layer of a deep learning architecture abstracts the input layer toward the output layer. That said, the current machine learning workflows are far from the new kind of data I am imagining: machine learning is based on hoarding massive amounts of data, which are so large and computationally resource-intensive that only large corporations can train these models.

The various examples show that data decay is possible but is an underdeveloped area of research. I imagine a new digital storage format in which data decays and abstracts over time. Data should self-abstract and generalize over time rather than listing everything I have ever searched for on Google. Further back in time, the list items should merge so there is no record of every search from ten years ago but instead of the general topics of interest from that year. Similar to the current conceptualizations of degrowth (Schmelzer et al. 2022) questioning the notion of development in political, economic, and social terms, we need to redesign our notion of data as a society. Within human memory, sensory memories become short-term memories in a fraction of a second, accumulating into fading long-term memories. The hippocampus plays a vital role in this transformation. For a sustainable and socially minded collective future, we will need a hippocampus for data: a clearing mechanism for database structures to abstract, compress, and forget. Rather than keeping 50 photographs of one moment, these images would turn into a memory by slowly decaying into each other. I hope that the beginning of the 21st century will go down in history as a time of data hoarding, as an excessive time of storing the unneeded, while in the near future, we will move towards a more sustainable data ecology in which data, like everything else, decays, merges, compresses, abstracts, and simplifies over time.

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