SWEDISH COLLEGIUM *for* ADVANCED STUDY

The Wittrock Lecture Book Series
No. 11

Life in the Digital Time Machine

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SWEDISH COLLEGIUM FOR ADVANCED STUDY (SCAS)

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Foreword

The Wittrock Lecture Series was instigated in 2019, in honour of the contributions of Professor Björn Wittrock. As Principal of the Swedish Collegium for Advanced Study (SCAS) in the years 1996-2018, and the driving force ever since its creation in 1985, Björn Wittrock has contributed significantly to the institute's strong position as an internationally renowned institute for advanced study, in addition to the social sciences and the humanities in Sweden, Europe, and beyond. His research has advanced several intellectual fields that include the sociology of ancient, medieval and modern societies, global history, intellectual history, and civilizational analysis.

The Wittrock Lecture Series is arranged annually by the Collegium. At these events, internationally renowned and state-of-the-art scholars are invited to give a public lecture on a theme that resonates with the scholarly profile of SCAS. Topics may range across the humanities and social sciences, and cover a broad spectrum of issues related to global history and modernity, globalization processes and social change, intellectual history, and the plurality of knowledge cultures. The lecture series also aims to address complex challenges facing contemporary society – from the shifting nature of globalization, to crises in democracy, or the future of governance and human civilization.

Christina Garsten
Principal, SCAS

Life in the Digital Time Machine

A Digital Time Machine

Can we conceive the future in non-linear ways? Digital time machines allow us to do so. They leave behind the familiar temporal chronology that frames our existence from birth to death by jumping forward and backward or by making a loop, roll or spin, just as airplanes do in aerobatic maneuvers. These time machines are not like the ones you know from science fiction, which transport you far into the past or into the future where weird things happen like meeting your former self or being older than your parents. The digital time machine in which we find ourselves thrusts us forward into a future that is unknown, and the trajectory runs through the landscape of complexity. It fills us with a mixture of unease, muted excitement, and real concerns. It is a machine in the sense that it embodies mechanical and organic components, with lots of electronics mounted around them, driven by mechanisms we barely understand. Digital machines are complex assemblages of computers, sensors, data, algorithms, and the infrastructure needed to keep them going. They have been designed to mimic human capabilities, but given their otherness as machines, they deviate from them in important respects.

We tend to think of digital machines becoming more autonomous, but they are still designed by humans. They need energy that must be supplied through vast, although largely invisible infrastructures. Machines raise questions not only about their technological functioning, but also like: Who is in control? Who steers such a machine and, as a time machine, how far does it allow us to see into the future or reach back into the past? Moreover, it is a digital machine, which for many stands for something that is rather abstract and mathematical. The digital part of the machine resembles a black box, neatly packaged into shiny gadgetry when seen from the outside, but impenetrable when one wants to understand what it is inside and how it works. What we know is that the black box is full of algorithms, sets of rules to be followed by calculations. We have been told that these algorithms can learn on their own and that they are capable of inventing their own rules. This stunning capability lets them perform amazing feats, like beating the world's best Go player, which is why most people find them somewhat scary.

And then there is Life. I do not refer to some of the ultimate questions about the origins of Life or its meaning, nor the uncanny resemblances between the mechanisms of self-replication in machines and self-reproduction in living organisms like cells. Such questions have been debated since the beginning of what we now call the computational revolution, which has unleashed an unprecedented transformation of our societies, the ways science advances, and how we live our daily lives. Life in the digital time machine exposes us to many novel experiences that are often felt to be overwhelming. Somehow, we need to integrate, appropriate, or adapt to what is happening to us and around us that originates in numbers, algorithms, and data, all wrapped up in electronic garb. But there is yet another dimension to Life, one outside the daily pursuits and struggles. It is Life on our planet, the only habitat we have; and if some people dream of setting up a second home in outer space, it is far in the future, if it will ever happen. Moving with the digital time machine, we cannot ignore what is happening in the natural environment and its further degradation or how climate change is disrupting habitual patterns of further economic growth. Humanity faces unprecedented global challenges that span different time scales, from short-term business cycles to long-term time scales that govern the interaction between oceanic and atmospheric circulations and that can abruptly come to a halt or reversal.

Let us briefly look at some of the most pressing challenges. The seventeen sustainable development goals, SDGs, as articulated by the United Nations provide a succinct summary and a rough roadmap of what needs to be done if 7.7 billion people on Earth are to have a halfway decent life in the future. The outlined goals fill the big picture and are arranged in a neat and easily understandable way. But they hardly show the messy reality that lurks underneath and that arises from the complex connectedness between them. Health and poverty are intimately related, and so are education and gender equality, which in turn affect health and poverty. They do not show the existing counterforces, the combination of vested interests, political leaders who deny climate change, and the general inertia when it comes to collective action on the global level. It suffices to look at the pictures of protesters that have rocked the capitals in many countries around the world over the past few months. They signal their anger against the ruling elites, but often also a nostalgic wish to return to a past that never existed in which national borders stood for protection against anything foreign that is felt to be intruding on national territory. The protesters carry banners with slogans and flags that proclaim that they speak in the name of "the people" and are directed against "the elites". Such outbursts of rage and resentment have been transformed by unscrupulous political leaders into waves of xenophobic and nationalistic populisms.

This leads to worries about liberal democracies being under threat, which are exacerbated by the unrestrained circulation of fake news and hate speech in the social media, the micro-targeting of specific groups before elections, and the fear of foreign interference. The lure of the Leviathan has returned. This iconic figure from the 17th century, proposed by Thomas Hobbes during the English Civil War, pictures a society gripped by fear of violent death and denies the possibility that there could be a common good pursued by the political community. The only way out is to transfer the rights of individuals to govern themselves to the sovereign, the Leviathan. The new ruler is an automaton who now has the right to act for the citizens. It is remarkable that a growing number of people today would give preference to artificial intelligence over a political system anchored in a liberal democracy. They hold that an AI agent would be much more efficient in making decisions than the bickering of today's politicians and the tedious democratic procedures that end up in political compromises.

The response to the unprecedented global challenges has also spurned new initiatives that can be summarized as being directed towards achieving a "Green Deal". The European Union, for instance, has set itself the ambitious goal of reaching a halt to net emissions of greenhouse gases by 2050 and of decoupling economic growth from resource use. Other initiatives put old ideas into a new green garb when demands are voiced to abolish capitalism or to transform it into a "green capitalism", whatever that might be. Together with the efforts to stem the tide of populism, these are attempts to find a way to smoothly transition from modernity's belief in progress to a new narrative fit for the challenges of the 21st century. It has become obvious that the narrative of progress that originated during the European Enlightenment and became substantially linked to industrial and economic progress during the age of modernity has lost much of its previous luster. With its appealing message of steady improvement and that the future will be better than the present, it may have served us well in the past, but it is on its way out. According to survey data from several Western countries, a majority now believes that their children will not have it as good as their parents, and empirical income data show that almost half of US working class men now earn less than their fathers did at the same age. The widespread feeling that the narrative of progress can no longer be upheld and is failing them is no longer restricted to those at the bottom of the socio-economic hierarchy. It has definitely reached the middle classes, at least in Western countries. The time machine of progress is sputtering.

Discovering Spatial Finiteness

Let me shift gears and take you back in history to the middle of the last century. In 1955, John von Neumann wrote a short article in a popular review with the title "Can we survive technology?" He summarizes the argument behind the question as follows: "For the kind of explosiveness that man will be able to contrive by 1980, the globe is dangerously small, its political units dangerously unstable."[1] The technology he is speaking about is not just any technology, but the dominant technology of the age: nuclear technology and, in particular, nuclear weapons. With the benefit of hindsight, we can see the irony of history at work. John von Neumann was a mathematician and an engineer, a polymath and one of the great figures behind the computational revolution. He was the one who, in the 1940s, laid out the logical basis of what it takes to make a machine self-replicating, describing in mathematical detail the mechanisms of such a machine. At the Institute for Advanced Study in Princeton, he was instrumental in building the first working prototype of a computer. The irony consists in not mentioning with one word what later became the dominant technology. Instead, he argues that as technological progress advances, it expands geographically. The Industrial Revolution consisted in making more and cheaper energy available, enabling more and faster communication, and easing the monitoring of human activities. But technological acceleration met its limits as most timescales are fixed by human reaction times. Hence, the geographical scope was extended until it too met its natural limits, the size of the Earth. This limitation induces instability. The planet had become too small for the two superpowers facing each other with their destructive nuclear potential. This was the first discovery of technology, as the foremost manifestation of human ingenuity, meeting its limits in the spatial finiteness of our planet, the only habitat to guarantee our survival.

Today, our worries have shifted. The nuclear threat is still there, but it has receded into the background. Non-proliferation treaties and partial nuclear test bans have been signed. Since 1947, the members of the Bulletin of Atomic Scientists release an annual report symbolized by the Doomsday Clock as a metaphor for how close humanity has moved towards a global catastrophe from unchecked scientific and technological advances. Today's worries have largely overtaken the old ones about the nuclear threat. Instead, next to environmental concerns, the main focus is on the possible use and abuse of digital technologies and the thinly veiled anxiety that we will begin to resemble these machines and lose what makes us human. The specter of a totalitarian surveillance state based on facial recognition and other means of digital tracing of citizens is never far away, outperforming the dystopic visions of Orwell's 1984. Worries also arise about the possibility of a *singularity*, as raised

by Ray Kurzweil in 2005. This is the hypothetical future moment at which digital technologies become uncontrollable and irreversible. An intelligent agent will reach the state of self-improvement cycles that leads to a veritable explosion of artificial general intelligence resulting in a superintelligence that surpasses all human intelligence. As frightening as such prospects may sound, for most people the more immediate concern is that of the future of their work. While there is agreement that digitalization is already wiping out a number of jobs, there is also consensus that new ones will be created. No one can say how many jobs will be lost, nor, and perhaps more importantly, does anyone know how fast the replacement of old jobs by new ones will occur and how many people will get caught in the looming technology trap.

Another returning question is whether we have peaked. It sounds familiar and has been posed time and again with regard to the possible exhaustion of fossil fuels. It seems we are far from running out of oil, which is more an issue of geopolitics concerning agreements on restricting the amount of oil to be extracted and the state of advanced extraction technologies using digital solutions. Oil, it seems, has not peaked yet, and green technologies are still on a slowly rising slope in catching up. But in many other respects, the question of having peaked resurfaces. Complexity science shows us numerous models of complex systems, all of which are prone to collapse when certain conditions are met. Tipping points are inherent in complexity and thus to be found in financial systems, health care systems, and, most ominously, in the global climate system. What may look like a peak in reality may just be the critical point before collapse.

These forays into the vulnerability of our dealing with various technologies only confirm what social scientists have known all along: technology alone will not save us. Technologies bring enormous benefits, but society must decide who benefits from them and how. Technologies need to be controlled and regulated, and much depends on who controls and regulates. If too much is left to the power of large transnational corporations, it is difficult to align them with the functioning of a society that is based on values of inclusiveness and social justice.[2]

One possible tipping point of global importance and dimensions is the growing awareness that we have arrived in a new epoch, the Anthropocene. Ever since Nobel Prize laureate Paul Crutzen proposed the term in the beginning of the 2000s to mark the fact that human activities are now exerting a significant impact on the Earth system and its climate, the idea of the Anthropocene has gained in visibility, popularity, and acceptance. It has become a concept that represents the dire state of the planet and combines it with a call for urgent action. It appeals to us to assume stewardship for a living earth of which we are a part. Officially, the Anthropocene still awaits approval from the timekeepers of the age of the Earth, the International Union of Geological Sciences. Under their auspices, the International Commission on Stratigraphy has set up an Anthropocene Working Group to submit a report by 2021 on whether the geological markers can be found that are required for recognition to become a new subdivision in the chronological sequence of geological times. The "golden spike", the technical term, consists in finding geological traces of human activities in rocks and various sediments of the earth. Among the most prominent candidates are the radioactive traces left in the locations where early nuclear tests were carried out in the 1940s. The official decision will have largely symbolic significance, but the Anthropocene introduces and confronts

us with time scales outside the ones we are familiar with, those of geological times. Humanity faces a temporal dilemma, as we do not know how much time is left to drastically cut back on CO_2 emissions and other damaging activities before we slide into an environmental and climate change catastrophe. The short-term temporalities governing human decisions and action are up against the temporal complexities of long-term time scales over which we have little or no control.

In retrospect, we can observe that different strands of large-scale scientific and technological developments began to converge with equally large-scale and impactful processes of human activities in the period from the 1940s into the 1950s. One of the strands is the computational revolution, starting as early as Alan Turing's famous paper in 1936. George Dyson's historical reconstruction of the main protagonists, their ideas, and scientific-technological accomplishments in the Institute for Advanced Study in Princeton, which he dubbed "Turing's Cathedral", distinguishes the time before and after Turing. The stored-program computer as conceived by Alan Turing and delivered by John von Neumann broke the distinction between numbers that mean things, and numbers that do things.[3] Connected to what happened at Princeton, the 1940s were also the period of the Manhattan Project, leading to the atomic bomb. After the end of the war, significant scientific-technological advances followed in material science, information theory, and semiconductors. Around 1950, a remarkable simultaneous surge can be observed in the rates of growth across a huge range of socio-economic activities, captured by indicators such as GDP and population growth, urbanism, water use, telecommunication, and tourism, on the one hand, and the dramatic changes in the trends affecting the earth system, such as ocean acidification, tropical forest loss, and the emission of greenhouse gases, on the other. This correlation between the take-off in socio-economic growth and the changes in the earth system is called the "Great Acceleration". The convergence between socio-economic activities and their geo-morphological and other environmental consequences is now continuously monitored by a Planetary Dashboard.[4] It has lost nothing of its relevance for the future of the planet. What started out as the discovery of spatial finiteness and the threat of a possible nuclear annihilation has turned into awareness of the enormous precariousness of the environmental niche we inhabit. Like other living organisms, humans, too, have been carving out a niche for survival from their immediate natural environment, just like worms and octopuses do.

Niche building is an evolutionary activity in which all living organisms engage. Only two centuries ago, humans were carving out a niche that allowed them to industrialize their societies, which eventually improved their living standards and well-being, albeit at a huge cost for the natural environment. Nature was first explored and then exploited. We have realized that there are spatial limits and limits to economic growth. This is the reason why we have shifted towards sustainability and cling to the hope that the sustainable development goals are not only lofty ideals, but feasible. At this point of evolution, the other long-term strand of scientific-technological development that had its origin in the 1940s kicks in. The digital or computational revolution has now become a ubiquitous process of digitalization that invades every facet of human activities. This revolution is not based on geographical expansion anymore, nor on the use of bulk materials that have to be carved out from the earth. Instead, it lets numbers do things. It still needs a lot of energy in the form of electricity, rare earths, and large, but mostly invisible infrastructures. It has enabled us to work at

speeds that surpass the human imagination, and with efficiency that surpasses all previous economic activities. We are in the process of building our next niche for the largest population ever living on earth. It is a digital niche.

Shifting Our Temporal Bearings

Almost unnoticed, these large-scale developments leading up to the present brought with them changes in the experience of time and in the temporal regimes in which social life is organized. The arrival of the Anthropocene entails a major confrontation between the short-term temporal range that frames political action, often down to the length of election cycles, temporal arrangements between the generations that entail difficult questions about future discounting, and the confrontation with long-term geological time scales. The birth of the digital universe initiated a completely new temporal regime. It complements the lived experience of time framed by the structures of social time and the arrow of biological time inscribed into us and leading from birth to death. In contrast, digital time is based on computational operations that can be reiterated at will or randomly mixed at speeds beyond human perception and imagination. But speed alone is not what makes an AI perform better than a human. The principal effect of faster machines is to shorten the time needed to achieve a result. Computers also have limits. There are those imposed by physics, but the more interesting ones are the kinds of problems a computer cannot answer. Turing himself gave example of problems a computer cannot solve. While important for mathematics, they do not seem to restrict practical operations. Rather, limits come up when problems appear to have exponential complexity that renders them intractable.[5] Dealing with complexity poses the problem for us that I mentioned in the beginning: can we conceive the future in a non-linear way?

When the first digital clocks were introduced and when time synchronization became radio-controlled, the display on the clock no longer showed a finger moving in a circle dubbed clockwise, but only showed sequentially shifting numbers. People wondered whether this would alter the social experience of time. The evidence remains inconclusive, but what followed was a kind of individualization of temporal experience. Clocks in public places disappeared and were substituted by the numerous tiny clocks built into almost every digital device. More recently, organizations began to shift their time management to digital calendars as part of a more general trend towards deploying digital assistants whose tracking capacities and behavioral algorithms are claimed to solve the problem of how best to organize the time in our lives.[6] Technological artefacts have always shaped our experience of time and generated new temporalities, but the intrusion of digital time into our lives adds a very special note. It alters our experience of *eigenzeit*. The endless multiplication of the amount of electronic data and the increasing density of networks create a new, technology-based set of options to satisfy the longing for the moment: medial *eigenzeit*.[7]

Our temporal bearings are shifting in unexpected ways. The greatest shifts occur among the concepts of past, present, and future. One of the central theses of my book *Eigenzeit*, published in the memorable year 1989, concerns the dissolution of the demarcation line between present and future. "The extended present has chosen the future and not vice versa," I wrote.[8] The boundaries between these categories have never been fixed, showing great variations over time and across different cultures. The future can be sharply demarcated from the present, for example as heaven or hell in the afterlife. The past was often considered dangerous, thought to be inhabited by dead ancestors or ghosts that attempt to make their way back into the company of the living. Such historical shifts reflect how our ancestors tried to accommodate their lived experience with its burdens and hopes and an imaginary cosmos that transcends the lifespan of humans and is not bound to end with death. The scientific worldview has supplanted such imaginaries. The scientific and technological means at our disposal have vastly extended our knowledge of the past and made it possible to generate knowledge about the future. This puts all the more pressure on the present, which we cannot escape.

The enormous amount of information to which we have access and the increase in real and imagined opportunities entice us to engage in ever more activities that rapidly fill twenty-four hours. This leads to a compression of time in the present. Time feels like it is being squeezed, and the density of activities and of ever smaller temporal units that regulate what we do induce the experience of temporal compression. Modernity was largely characterized by feeling overwhelmed by the dazzling speed of machines that required people to adapt to them. The combination of technological and social change resulted in the feeling of being swept along, with everything accelerating. Currently, we may still feel that too much is happening too quickly, but the linear concept of time that became the dominant temporal regime through industrialization had to give way to multiple, often conflicting temporalities. Acceleration is no longer a dominant experience, as the speed of computers renders any comparison futile. Instead, we feel emotionally and informationally overburdened, not least through the digital technologies that have become ubiquitous in our lives and surroundings. Let us look at what happens at the boundaries between the present and the past and the ways the future has invaded the extended present.

The deep past reaches into the present as science and technology enable us to see far back into what happened a very long time ago. Take the example of the LIGO detector. It took half a century and an international team effort to build this large-scale physics experiment whose aim was to detect cosmic gravitational waves that Einstein predicted more than a century ago. The waves originate from the collisions and coalescences of neutron stars and black holes tens of millions of light years away from the earth. Yet, these and other cosmic events reach us as if they were happening now, just as we easily assimilate the images of Pluto, Saturn, or newly found exoplanets and other phenomena from outer space. But it is not only the past from outer space that joins the present. In the 18th century, geologists looking for fossils were as interested in finding minerals as in determining the age of the earth. Today, the booming field of paleogenomics is rewriting the history of human evolution almost on a day-to-day basis. DNA sequencing and other technical advances allow us to retrace the lineages of human ancestry by means of extraction from ever smaller bone and other specimens. Our evolutionary history, a twisted history of human migration, conquest, and assimilation, thus becomes an integral part of the present.

Interacting with human history poses greater challenges than conversing with phenomena in the universe. The questions we pose to history are always shaped by the concerns and interpretations of the present. This is why historians are still working on the French Revolution, although one might think that almost everything about it is known by now. The closer one moves to the present, the more the interpretation of recent historical events begins to resemble a minefield. History, as already Thucydides noted, is written by the winners. The official historical narratives are often at odds with the informal accounts and the lived experience transmitted within families. It can also become politically explosive. David Reich, one of the leading scientists who have transformed the field of ancient DNA from a niche pursuit to an industrial process, was involved in drawing up a map of some thirty highly differentiated population mixtures that occurred in human history. He tells the anecdote of a collaborative project with a group of scientists in Hyderabad in India who had a vast collection of DNA samples that represented the extraordinary human diversity in India. Initially this caused a lot of excitement. The analysis showed that Indians today descend from a mixture of two highly divergent ancestral populations, one coming from the northwest, the region known as Western Eurasia, and the others coming from the southeast, who are distantly related to East Asians. When he discussed the first results with the Indian colleagues, their reaction threatened to nix the project. They feared that the idea of a massive migration from outside India with such transformative effect could be politically explosive. In the end, a change in language saved the project. Today's Indians, the research findings now read, are the outcome of mixtures of two highly differentiated populations, renamed "Ancestral North Indians" and "Ancestral South Indians" with everyone in mainland India a mix.[9]

Recent efforts to interrogate the past increasingly use digital means. The aim is to broaden the data base of the otherwise scant evidence that remains. The field of quantitative history is also known as cliodynamics. Sheshat is the name of a huge data base intended to provide answers to hitherto unresolved questions and to test various hypotheses based on new and increased amounts of evidence. One recently discussed question concerns the evolution of complex societies and, in particular, whether moralizing and punishing gods preceded or followed the rise of complex societies. Based on a number of quantified indicators as proxies, the research team has arrived at the preliminary answer that complex societies precede moralizing gods. In other words, these gods were instruments used by the dominant elites to control the behavior of the population.[10] I mention this here as an example, not because it is the last word for a question that specialists have long debated. It is an example of how the social sciences and humanities can push forward by including new data in their research that will allow them to ask older and often unanswered and controversial questions. The answers will be further debated and hopefully open the way to new forms of genuine collaboration across the quantitative vs. qualitative divide. Engaging with history in different ways and from diverse perspectives becomes ever more important when the future becomes ever more unlike the past.

In a famous quote, the Canadian sci-fi writer William Gibson observed, "The future is already here, it's just not evenly distributed." A sharp observer of what happens around him in society, he recently noted a kind of "future fatigue" setting in. During his lifetime, he remarks, the future has been a cult, if not a religion, based on the belief that everything will be better or even perfect. Now people seem to be losing interest in the future. Throughout the 20th century, people used to evoke images of the 21st century, while rarely does anyone now invoke the 22nd century. The excitement seems to be gone as the focus has shifted to the Now. We may have even come to have no future.[11] The present is overloaded with information that invades every facet of daily life, adding to the pressure already felt because of the insatiability of wants and their immediate gratification promised by digital technologies. If the appetite for the future has waned, the reason is that there is too much of it that has to be digested now.

The future has arrived and it takes hold of the present. It may overwhelm us with information and may distract us, but even the long-term time scales on which climate change operates have moved into the present faster than expected. The title of the Global Sustainable Development Report 2019 published by a group of scientists for the United Nations proclaims, "The Future is Now". The exponential infection rates of the SARS-CoV-2 virus demonstrated with frightening clarity how quickly a looming disaster that seemed somewhere in the future and geographically remote can invade – and infect – the present. In this case, at least, one cannot say that nobody saw it coming. Epidemiologists are on record as having issued warnings about a next pandemic. This is not a black swan, one of those unpredictable and rare events with catastrophic effects. Like earthquakes, epidemics are predictable and will continue to happen, but the specifics, especially the timing, are not known. Due to the high connectivity in the infection and transmission lines, the spread in a pandemic is also non-linear, with the output disproportionate to known inputs. Thus, the Corona virus is also a part of the future that is already here. It remains latent until an outbreak occurs, often triggered by a chain of coincidental events. In retrospect, we will reconstruct the why and the what and attribute blame. As for the timing, we can only try to be better prepared for the next disaster.

The Predictive Power of Algorithms

The desire to know the future is as old as humanity. All cultures are known to have practiced some kind of divination by turning to the higher powers, be it the gods, God, or Fate, to reveal what lies ahead for human beings. The shared assumption is that human destinies have already been determined and are known to the gods, while humans remain in ignorance. Practices of divination were carried out by practitioners, intermediaries with special training and skills to interpret the signs transmitted from another realm. In some parts of ancient China, for instance, the shoulder blades of sheep or the shells of tortoises were held above fire to induce cracks in the bones that would then be interpreted by the divinatory experts. These Chinese oracle bones are now thought to display what might have been the origins of the Chinese script. Wanting to know the future may inadvertently have led to a technique of preserving the past for the future.

Elena Esposito has drawn attention to some fascinating similarities between such practices of divination and the algorithms used to make predictions about future human behavior. Ever since the rise of statistics, modern societies have been using them for administrative purposes, but also as an efficient way to manage uncertainty. Based on large numbers and deploying statistical tools, the patterns detected in the past were extrapolated onto the future. She contrasts the "governance by numbers" based on statistics with the predictive algorithms that feed on Big Data. Predictive algorithms signal a return to divinatory practices. They do not address averages and general trends in the population, as administrative statistics do. On the contrary, predictive algorithms address a single individual who is the target of their direct intervention. This is where they resemble magical thinking and ancient divinatory practices. Divination was based on the assumption that the future could be seen in advance and was revealed to the supplicant in strictly

regulated ritualistic settings. Likewise, algorithmic predictions claim to have knowledge about the future and intervene in human behavior by addressing the individual directly. This has far-reaching implications for society, as it is a way of managing the uncertainty of the future that differs from practices based on averages, means, or Gaussian distributions.[12]

Where does the predictive power of algorithms come from? If one wants to understand the history of the computational revolution and the waves of digitalization that followed, more is needed than a chronological account of who did what or how the ideas, mathematical concepts, and physical machines to execute numerical operations were brought together. The current situation is the result of the convergence of three different strands. First, there is the enormous amount of data that has become available and that continues to grow at stupendous rates. Big Data is not only collected from smart phones and the digital traces we voluntarily leave behind with our credit cards and by letting Google know our location. The pool of data is also expanded by sensors that populate public spaces and intrude into private homes. As algorithms advance in their capacity beyond mere face recognition, data are also generated by our eye movements and emotional arousal that reveal when and how much attention we pay to something. More data covering more of what we do, think, and feel will undoubtedly follow.

The second converging strand is constituted by algorithms, the set of rules to achieve the function for which they have been designed. Computer scientists have been working on algorithms for decades, initiating and pushing the computational revolution that is transforming our societies. Initially, algorithms were designed to follow logical operations that failed to live up to expectations. A period when funding dried up followed, which those who lived through it remembered as the "AI winter". It was only when the combination of computing power, optimizing techniques, and the availability of massive amounts of data came together that a new generation of algorithms arose that came to dominate the field from 2012 on. They are broadly referred to as deep learning or machine learning models. This second generation of algorithms is based on a simplified version of neural networks that turned out to be astonishingly efficient. They are able to create rules themselves with relatively little intervention from humans by interacting with massive amounts of data; exactly how they do it is poorly understood. The dazzling achievements by an AI system to teach itself chess from scratch and of another AI system to beat the world's best Go player are merely the most publicized feats enabled by forms of deep learning.

Without the third strand, the convergence of the second generation of self-learning algorithms that need huge amounts of data to learn from and their availability would not have been sufficient to get the field to where it is now. This is the huge jump in computational power, the precondition for algorithms and Big Data to detect patterns in data from which predictions are extrapolated. Whereas the first generation of algorithms was crafted entirely by humans, the algorithms derived from machine learning are really technological products, owned by the companies that design them, and many of them kept secret. Deep learning has led to rapid industry-driven advances in AI and to where we now stand. But not everyone in the AI community is content with the "unreasonable effectiveness" of deep learning algorithms. Some scientists and mathematicians working at the interface of computer science, mathematics, statistics, and computational complexity theory find it deeply unsatisfactory that nobody fully understands what algorithms are actually doing when they learn. They resent that we should sit back and let a machine fill a blank slate without asking the most basic question that makes us human, the question Why?. Instead of being overwhelmed by well publicized performances of a machine beating a human, we will need a much better understanding of where and for which tasks each specimen of algorithm is optimally to be deployed and what their limitations are. Eventually, we will have to understand the relationship between cause and effect. We have Big Data and Artificial Intelligence, but it will take the courage to ask the Big Question of Why and a lot of hard work to answer it.[13]

The Digital Time Machine in which we find ourselves is driven by the predictive power of algorithms. We no longer practice divination, but we are as keenly interested in what the future holds as were our ancestors. Voluntarily and carelessly, we leave digital traces of our behavior everywhere, traces of what we buy, eat, and whom we meet. We wear fitness bands and, eager as we are to continuously monitor the state of our health and well-being, we have adopted the self-tracking of our various physiological states and the up- and downswings of our moods as an expression of our lifestyle. What Shoshana Zuboff calls "surveillance capitalism" summarizes our collusion in delivering information about some of the most intimate features of our lives to big transnational corporations in exchange for more information about ourselves.[14] We are especially keen to know more about our future, as predictions satisfy our desires. There are uncanny moments when we are startled by the realization that an anonymous AI system may know us better than we do ourselves. We then voice concerns about our privacy and call for better regulation and protection before resuming our habits.

The digital time machine lets us see further ahead, while the future has moved closer into the present and the boundaries between them become increasingly blurred. Paradoxically, the message delivered by prediction is largely felt as reassuring, regardless of its content. In the precarious task of coping with the inherent uncertainty of the future, we derive satisfaction from knowing at least part of it. In line with divinatory practices, the more the prediction that comes from an algorithm addresses us as individuals, the more we feel we are in control. Analogous to personalized medicine, prediction is delivered in personalized form. It does not matter that nobody knows how the algorithm has been designed and how it actually works or that the scientific objectivity attributed to it is a myth. We may even accept that it is biased, as it carries the biases introduced with the data it has been fed. Even the biases are personalized. We can now see into the future, and the knowledge that comes with the prediction will help us to master it – or so we believe. This can be the risk of developing a certain disease, the banalities of our daily behavior that follow familiar and habitual paths, or how we can make money more easily or be more successful. As a technological product, predictive algorithms have efficiently been built into veritable prediction machines that have quickly sprung up on the market. They respond to different kinds of needs and satisfy different desires. All of them promise to allow us to see further into the future. Let us briefly look at some of these prediction machines.

The advances of modern science and notably of physics are based on the invention of new theoretical concepts and on testing the predictions based on them. This is why scientific predictions are still considered the hallmark of modern science. Between the mid-1800s, when probabilistic prediction was introduced into physics, and today, an interesting conceptual change in the meaning of prediction occurred. Initially, predictions in statistical mechanics formed the basis for a novel,

stochastic view of the laws of nature. With the discovery of quantum mechanics around 1900, questions about the role of chance in the laws of nature and how this affects predictions were introduced. In the present, the interpretation of prediction is related to the investigation of complex systems. In this development of the meaning of scientific prediction, a tradeoff between precision and the range of applicability can be observed.[15] In other words, the wider the set of problems to which the notion of prediction is applied, the weaker the forecasts become. While this may need to be taken into account in science, the spillover in applications into society has been huge. Wider applicability has been translated into a highly valued efficiency.

One field in which the applicability of scientific predictions based on mathematics and simulation models has been enormously successful is weather forecasting. The weather prediction machine now at our disposal is a great scientific and technological achievement. Its origins go back to the beginning of the 20th century. Predicting the weather is based on what has become a global infrastructure devoted to constant observation and prediction. It is indispensable for transport and communication, for disaster warnings and preparedness around the world, including the monitoring of global climate change. The fascinating story of its origins and further development is well told by Andrew Blum. It follows the various pathways in which mathematical calculations and the creation of new networks and tools for observation turned meteorology into a mathematics-based, reliable science. But the paradigm shift in weather forecasting came with advancements in computer simulation and a vast amount of data collected from satellites and instrumental balloons, thermometers, barometers, and anemometers. Weather forecasting depends on the use of supercomputers and a purpose-built telecommunication system to bring it all together. It is possible now to follow live on a computer screen a major storm approaching or the continuously updated projection of the pathways a hurricane will take. Weather forecasting is available on specialized weather channels and by means of apps on our smartphones. Robots are increasingly taking over what human modelers used to do. The range of decisions depending on accurate weather forecasts, whose commercial and economic usefulness was never in doubt, has also widened. The next challenge for predictions based on computer simulation is to move from forecasting the weather to the complexities of the climate system. "At the beginning of an era when the planet will be wracked by storms, droughts and floods that will threaten if not shred the global order, the existence of the weather machine is some consolation."[16] Let us hope that progress in building a climate prediction machine will come in time.

Compared with predictions in science and those used for weather forecasts, the commercially available products are very simple prediction machines. But they make money and promise to make even more. One of them is presented by its authors, three economists, as embodying the simple economics of AI. The argument goes as follows: the core of AI rests on its ability to predict the behavior of consumers and clients. Organizations and firms need to make decisions all the time on different levels. This requires some form of prediction, which is making AI useful to organizations. With the spread of AI across many industries, the costs of prediction go down drastically. This drop in price will lead to an increase in the price of affiliated products, just as lower-priced coffee will be complemented by an increase in the price of sugar and cream. When predictions become cheaper and, arguably, more accurate, this will change business models drastically. Seen from the perspective of the simple economics of AI, prediction is also defined in

a simple way. It is "the process of filling in missing information", meaning that this definition covers any operation that takes existing data to generate new information. In the past, accurate prediction for the organization had to rely on experts. They are more expensive and, as their ability varies, also less reliable. AI is changing this, so the argument is that replacing the predictions made by experts is more accurate, efficient, and much cheaper. By integrating AI in organizations' decision-making, the firm's productivity will be enhanced and so will its profit-maximizing strategies, job functions, and task allocations.[17] Q.E.D.

Another example takes us to the realm of creative work, where predictive algorithms are either co-opted as allies and predictive tools to enhance the artist's creativity or regarded as suspicious intruders. In a hugely successful public relations exercise at the Rijksmuseum in Amsterdam, a group of art historians, material scientists, data scientists, and engineers spent eighteen months to produce what they boldly advertise as "taking on a controversial challenge: how to teach a machine to think, act, and paint like Rembrandt". The project was organized by the J. Walter Thompson Amsterdam company, which calls itself the world's best-known marketing communications brand for its client ING, with Microsoft as its technical partner. The latest sophisticated digital technologies were summoned to demonstrate how much AI has matured to tackle projects that require human creativity. The aim was to predict what the next painting would look like if Rembrandt had painted it himself. In painstaking detail, Alison Landmead, a digital art historian, deconstructs this claim. She does not doubt that AI is capable of "creating" what passes for new art and bows in awe before the technical sophistication displayed by the project in full public view.

Rembrandt was famous for his portraits of contemporaries and his self-portraits. The algorithm was trained on a selection among them, and the "next Rembrandt" emerges out of this composite mixture. Langmead calls this a case of computer magic, because the entire performance resembles a stage magician's trick. What the visitors get to see is not how AI captures Rembrandt's creative sparks, which he so masterly demonstrated during his long, illustrious career. The museum visitors are presented with a result based on the extrapolation of the artist's style and painting averaged across different phases of his career, which, moreover, represents a somewhat arbitrary cross-section of different faces painted in different settings and contexts. Despite the admirable technological sophistication and the organizers' claims to showcase AI capable of matching or even surpassing the artist's creativity, it utterly fails as a prediction of what Rembrandt would have painted next.[18]

And yet – who has never engaged in speculatively imagining what the next great work of artists whom we admire would be like? The next Leonardo or a next Caravaggio? Art historians continue to debate the personal touches of these masterworks, a brushstroke here and a slight change of color there, the attribution of which is hindered as many of the admirable paintings were collectively produced in the masters' workshops. Unfinished pieces of classical music are acclaimed in concert halls with endings that have been added posthumously by composers following the master's style and spirit. Creative work has never been the exclusive domain of the lone genius. Artists, like scientists, communicate with each other and occasionally rebel against each other. Who influenced whom and when – can now be followed by network analysis that computes n-grams or distant reading. They enable the quantification and visualization of the connecting networks that cross borders, generations, and styles. Predictions of what would have come

next or what would have happened "if" or "next" are always welcome. They inspire the imagination, but they are as much the product of speculation as what AI can deliver.

If we were to set up a real "creativity test" instead of a flawed "Next Rembrandt test", what are the criteria an AI system would have to pass? The answer lies in the ruptures and discontinuities that mark the work of great artists and yet let us recognize that they are the result of how tensions within the artist's work have evolved and been negotiated. This is where the unpredictable side of creativity comes in and where we have to admit that chance plays a role in artistic endeavors as much as in science, where it is called serendipity. Randomness can be deliberately introduced into AI as a way to make it learn to be "creative". But as long as the machine is unable to predict a discontinuity that manifests the next step or initiates a new phase in the maturation of artistic creativity, it will not pass the test. It will remain a less inspiring example of what AI can extrapolate from Rembrandt's past work.

The Power of Prediction and the Illusion of Control

We face the paradoxical situation of having generated a very efficient instrument that allows us to see farther into the future, covering the dynamics of a wide range of human activities and natural phenomena, but we fail to understand the basic mechanisms that underlie them. In science there has always been a productive tension and interplay between advancing the understanding of phenomena and building instruments that test theories and predictions against what happens in the real world. The power of predictive algorithms is no longer confined to science. It has become highly profitable for our economies and has triumphantly swept across our societies. Harnessed by the marketing and advertisement industry, instrumentalized by politicians who eagerly seek to maximize the number of votes, quickly adopted by the shadowy world of secret services, hackers, and fraudsters and the anonymity of the Internet that facilitates the circulation of fake news and conspiracy theories – they all converge to convince the dazzled consumers, voters, and health-conscious citizens that this powerful digital instrument is there to serve their needs and latent desires.

The power of predictive algorithms is performative. It is able to make what it predicts happen. The phenomenon of self-fulfilling prophecies has been known for a long time. They are prediction-based beliefs or expectations that become true simply because people believe they will and adjust their behavior accordingly. As the sociologist William Thomas succinctly summarized in 1928, "If men define situations as real, they are real in their consequences." Once self-fulfilling prophecies begin to circulate widely, a prediction that was intended to cope with the uncertainty of the future quickly is transformed into a certainty that directly influences behavior in the present. Self-fulfilling prophecies are not just isolated incidents, like the run on a bank or the herding behavior known from financial markets before they became automated. People's propensity to orient themselves towards what others do, especially in unexpected or threatening occasions, is well known. In many subtle ways, the power of predictive algorithms has infiltrated the entire fabric of our societies and has become the key for increasing lagging productivity in the economy and for guaranteeing further economic growth.

Predictive algorithms allow us to make forecasts in simulation models of complex adaptive systems. They help to identify those features of the system that learn and evolve, all

in the context of the ongoing further gathering of information about the behavior of these systems. But here, too, a gap exists between the instrumental efficiency of algorithms and our understanding of how they actually obtain their results. I will not go further into what this potential schism between scientific understanding and machine-made predictions means for scientific enquiry and whether we will succeed in integrating the sciences of complexity with machine learning and artificial intelligence.[19] The power of algorithms to churn out practical and measurable predictions that are useful for our daily lives, for the management of health systems, for automated trading in financial markets, for making businesses more profitable, or for expanding the creative industries is so great that we easily sidestep or even forget the importance of the link between understanding and prediction. Understanding includes the expectation that we can learn how things work and that others can explain to us how and why, so that we can replicate and verify, fulfilling the requirements of the scientific method. There is no reason not to expect this also from machines if an algorithm claims to solve problems at least as well as a human. This is why we demand transparency and accountability from AI. In practice, we are far from receiving satisfactory answers as to how AI works, let alone an answer to the question of cause and effect.

But the need to understand remains the basis for the transmission of all knowledge and of culture. If we abandon the human desire to know why and to understand what holds the world together, we risk a return to a closed and deterministic world. It will be run by efficient prediction machines whose inner workings remain obscure. It will have ceased to matter how they work, as predictions often get things right and expand what we can see of the future. We will adapt our expectations and behavior accordingly. In such a world, it is easy to imagine surveillance becoming ubiquitous, as Big Data will get even bigger and data can be acquired without understanding or explanation. Eventually, we will be transformed into a predictive system ourselves, in which algorithmic forecasts can be checked against our behavior on an hourly basis, like traffic jams or an approaching weather front. Even our ability to teach others what we know and what we experience and to learn might begin to resemble that of a machine.

Luckily, we have not yet arrived in such a dystopia. We can still ask the question whether we really want to live in such an entirely predictable world in which predictions invade and guide our innermost thoughts and desires. A return to a deterministic worldview would imply that the open horizon of the future is closed again. It would mean abandoning a precious and hard-won discovery that was made only some two centuries ago. The historian Reinhard Koselleck describes the period between 1750 and 1850 as a threshold period that he calls *Sattelzeit (saddle period).* By following his research enquiries into how new concepts arise in history and how major conceptual changes are associated with major social and political changes, he was led to focus on how the concepts of the future change over history.

Just as a watershed on a mountain ridge separates waters flowing in different directions towards rivers and seas, the *Sattelzeit* marks the before and after in the experience and conceptualization of the future. It came to be seen as an open horizon. The gap between what he calls the "space of experience" and the "horizon of expectations" began to widen and a fundamental difference appeared between the past and the future.[20] The experience of the past with its slow pace and with life chances often restricted to inheriting those of the previous generation began to change. People began to grasp that their

lives could be different from that of their parents and grandparents. This not only mattered for the ways they gained their livelihood, but also included their habits, values, and worldviews. Above all, it enabled them to generate aspirations for a future that could be different, conceptualized as an open horizon.[21] This widening gap between experience and expectations ushered in the concept of the future as an open horizon. It was preceded and accompanied by dramatic changes in political and social life. Spearheaded by the French Revolution, these developments included the dissolution of the estate system, the early impact of industrialization, and the altered consciousness of history that together brought forth the concept of an open future. Unheard of changes in mentalities and social behavior followed. For the first time, it appeared possible to escape a predetermined destiny and to understand that one could shape it. It was a great discovery or, if you prefer, a great social invention.

In the first Wittrock Lecture, Jürgen Kocka analyzed how the emerging differences and changing interrelationship between past and future influenced modern historical thought. Other thinkers came to share Koselleck's highly influential work as a basic epistemological assumption. Kocka takes this one step further by adding that the study of the past influences one's "horizon of expectations", as well, while one's vision of the future affects the way one reconstructs the past and relates it to the present.[22] There can be no doubt that the impact of viewing the future as an open horizon is profound. For millennia, human beings who had lived in different periods and under very diverse circumstances invented cosmologies that sought to triangulate their struggle to survive with their relationship to the natural environment in which they had to carve out their living and a vision of transcendence. In every culture, one finds origin myths and often imaginary visions of how it all might end, sometimes linked together by notions of cyclical time. Whatever will happen has already been determined by some higher, non-human powers. The fate of humans is known to the gods, but humans are ignorant of it. The future has already been decided and one's destiny determined – this was the gist of humanity's beliefs over the largest part of its existence.

It is against such a backdrop of imaginaries, millennial cosmologies, religious prescriptions, and lived experience that the radical thought of the future as open has to be appreciated. Backed by modern science and technology that pushes the doors open wide, a new worldview came into existence that permits us to shape our destiny, at least to some extent. We may soon find ourselves at a new crossroads. If the predictive power of the algorithm takes hold in the social fabric and succeeds in making us transfer to it more and more of human agency, the return to a deterministic worldview can no longer be ruled out. So far, the applications of predictive algorithms in the social world are geared mainly towards the promises of a shiny, commercialized future. It is presented as an opportunity, without asking who will actually benefit and under which terms opportunities can be seized by whom. In a world beset by increasing inequalities, these are likely to become only further entrenched.

A return to determinism would accord priority to knowledge that is derived from a human-made instrument, an algorithm. This as a mere, although highly efficient, tool that would gain precedence over knowledge that is generated by the desire to understand – incomplete, erroneous, and contradictory as our understanding of the world, of each other, and ourselves may be. Determinism renounces the inherent uncertainty of the future and replaces it with the dangerous illusion of being in control. Instead, what I have called The Cunning of Uncertainty needs to be embraced. It leads us into the territory of what is still unknown and enlarges and enriches what we know. Basic science thrives at the cusp of uncertainty and opens the space of the possible.[23]

We have to continue our exploration and aim for understanding. After all, what makes us human is the possibility to ask the question *why do things happen, why?*

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