Paper

Technology and change: the role of information technology in knowledge civilization

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Abstract— The paper presents a reflection on the role of technology and, in particular, information technology in the era of knowledge civilization. Diverse perceptions of this era, the concepts of three civilization eras versus three waves, of a cultural platform versus an episteme of a civilization era, of a big change at the end of industrial civilization era are outlined. The first principle of cultural anthropology and the concept of cultural imperialism are recalled. The contemporary philosophy of technology is shortly reviewed. An interpretation of *Die Technik und die Kehre* of M. Heidegger from a technological point of view is given. It is shown that we should distinguish technology proper from the system of its socio-economic applications, and that the relation of technology proper to hard science and to socio-economic applications of technology forms two positive feedback loops; the one of socio-economic applications might be more dangerous in cases of social infatuation with technological possibilities or other misapplications of technology. It is shown that the technology of knowledge civilization era will differ from that of industrial era in proposing boundless number of diversified technological possibilities; thus, the Heideggerian warning against social infatuation with technological possibilities must be not only repeated, but also modified and strengthened.

Keywords—knowledge civilization era, philosophy of technology, definition of technology, technology proper versus its system of social applications, relation between technology, hard sciences, soft social sciences and humanities.

1. Introduction

As long as fifty years ago, there was no doubt, see, e.g., [1] that humanity developed because of tool-making, thus technology is an intrinsic human trait; that many old civilizations collapsed because their political leaders (pharaohs, kings, head priests) used the tool-making and the technological abilities of their people for too ambitious goals; that technology is a way of mastering nature but nature often punishes those human civilizations which use their technological abilities too ambitiously. All this simple, basic truth has been, however, questioned during last fifty years, while social science and humanities started to look at technology as an autonomous, dehumanizing and enslaving force that in itself leads to an excessive use of its own. Despite these accusations, technology has brought about the information revolution that includes also the dematerialization of work: automation, computerization and robotization relieved humans from most of heavy work and created conditions for an actual realization of the equality of women. This prepared a new civilization era that can be called global knowledge civilization (or simply *knowledge civilization*, since it will last many decades yet before this type of civilization becomes truly global). This development solves many old problems and brings many hopes, but also brings new problems and many dangers.

Thus, it is necessary to reflect what will be the future role of technology in the starting era of knowledge civilization. Having almost fifty years experience in developing information technology and over twenty years in assessing its future developments and impacts, the author of this paper intended to write an article on such future technology assessment. However, the basic character of temporary civilization changes has induced the author to check also the philosophy of technology; and the state of contemporary philosophy of technology appeared to him both deeply disturbing and frightening. Disturbing, because the writers in this field seem not to be able even to arrive at a consensus how to define consistently what technology is; moreover, they propose definitions and interpretations of technology not acceptable to a technologist. Frightening, because we need a basic philosophic reflection on the future role of technology in knowledge civilization; but if philosophy is not even willing to listen to the opinion of technologists what they truly do, then it will not be able to understand this apparently distinct human culture. This can have disastrous results for the entire human civilization on global scale, because the historical too ambitious uses of technology by political leaders seem to be based on similar misunderstandings.

Therefore, we must first reflect what has happened during the last fifty years, when three different cultural spheres apparently separated themselves: of social sciences with humanities, versus hard sciences, versus technologists; how these cultures view each other; how does this influence the philosophy of technology; what is and what is not the definition of technology acceptable to its practitioners. First upon clearing this background we can discuss the future role of technology in knowledge civilization, its promises and chances versus its problems and dangers. We must start, however, with a review of some basic features of the starting era of knowledge civilization.

2. The era of knowledge civilization

2.1. Diverse perceptions of a new era

There is a voluminous literature on the subject of *information society* and current *information revolution*, see [2–9]. In this voluminous literature, there are diverse views, diagnoses, prognoses, judgments, prescriptions – and a universally accepted, slowly evolving core. There is an universal agreement that we are living in times of information revolution and this revolution leads to a new civilization era, in which knowledge plays even more important role than just information, thus the new epoch might be called knowledge civilization era. However, many other aspects of this development are uncertain.

Concerning the date marking the beginning of new era, we shall follow the method given by historians, in particular F. Braudel [10]. Braudel defined the preindustrial era of the beginnings of capitalism, of print and geographic discoveries, as starting in 1440 with the improvement of printing technology by Gutenberg, who promoted broad applications of printing press, and ending in 1760 with the improvement of steam engine technology by Watt, who made possible broad applications of steam machine; this started the next, industrial civilization era. Similarly, we can take the date 1980, related to the improvements of computer technology (personal computers) and network technology (broad applications of new protocols of computer networks), which made possible broad social use of information technology, as the beginning date of the era of information and knowledge civilization.

2.2. Three civilization eras versus three waves

In such a way, instead of speaking broadly about *three waves* of *agricultural, industrial, information civilization* such as discussed in [5], we concentrate more precisely on three recent (they are not the first, nor they will be the last) civilization eras that are marking the slow globalization of mankind civilization. These are the eras of:

– *preindustrial civilization*: print, banking and geographic discoveries;

– *industrial civilization*: steam, electricity and mobile transportation;

– *information and knowledge civilization*: networks and mobile communication, knowledge engineering.

For a more detailed discussion, see, e.g., [11].

2.3. The cultural platform and the episteme of a civilization era

It is important to note here, however, that each of these eras started basing on a definite cultural platform of new concepts and ideas formed even before the beginning of the era, see [6], which after some time was followed by the formation of an episteme characteristic for the era, see M. Foucault in [12]. While Foucault rightly stresses that the way of constructing knowledge in a given era is very specific and emerges some time after the beginning of the era (he dates the emergence of the *preindustrial episteme* at least a century after Gutenberg and the emergence of the *industrial episteme* at least half a century after Watt), he does not pay much attention to the origins of an *episteme*. But before Gutenberg we had the beginnings of Renaissance, before Watt we had Newton and French encyclopedists; the episteme of knowledge civilization is not formed yet, but the destruction of the *industrial episteme* and the construction of a new *conceptual platform* started with relativism of Einstein, indeterminism of Heisenberg, with the concept of feedback and that of deterministic chaos, of order emerging out of chaos, finally – with the emergence principle.

The last point deserves an explanation, because its significance is not universally perceived yet, particularly in philosophy. Mathematical modeling of dynamic nonlinear systems was highly developed already fifty years ago, with diverse applications but especially in control engineering, see, e.g., [11] for a more detailed discussion. But such modeling has lead to the concepts of deterministic chaos and of order emerging out of chaos, see, e.g., [13].

Thus, the study of mathematical models of nonlinear dynamic systems resulted in *a change of the reduction paradigm to an emergence paradigm, in a rational justification of the emergence principle: of new systemic properties emerging on new levels of complexity, independent of and irreducible to the properties and parts on lower levels*. Parallel, this emergence principle was justified empirically by biology in its concept of punctuated evolution, see, e.g., [14]; but the rational justification was important because it has shown the emptiness of diverse ideological attacks on the concept of evolution. This change of perception was additionally supported by a pragmatic justification given by technology, in particular telecommunications and information science. An example is the ISO/OSI (International Organization for Standardization/Open Systems Interconnection) model of seven layers of a computer network. This model stresses that the functions of such complex network not only cannot be explained by, but are also fully independent of the functions of its lowest *physical layer*, by the way electronic switching elements work, repeat and process signals. On each higher layer, new functions and properties of the network emerge. The functions of the highest *application layer*, are responsible for application software and are absolutely independent from the way the lowest layer works; they would be the same even if the switching in the lowest layer would be fully optical or even quantum mechanics driven.

The ISO/OSI model was used to unify the functions of various network protocols from TCP/IP (transmission control protocol/Internet Protocol) family (IP, TCP, UDP, etc.) that enabled the information revolution and brought digital information processing potentially to every home on our globe. The authors of the ISO/OSI model were not necessarily aware of changing the reduction paradigm to emergence paradigm. They simply wanted to conquer the complexity of the modern telecommunication networks and needed to assume the emergence of new properties of the system on higher layers because otherwise they would be lost in details. They were probably also unaware of the fact that the theory of hierarchical systems, including the theory of systems with many layers of qualitatively different functions, irreducible to the functions of lower layers, was developed some time earlier by control system theorists, see, e.g., [15].

The *industrial episteme* believed in *reduction principle – the reduction of the behavior of a complex system to the behavior of its parts* – which is valid only if the level of complexity of the system is rather low.

With very complex systems today, mathematical modeling, technical and information sciences adhere rather to emergence principle – the emergence of new properties of a system with increased level of complexity, qualitatively different than and irreducible to the properties of its parts.

It should be noted that the emergence principle is the essence of complexity (essence in the Heideggerian sense which will be discussed later) and means much more than the *principle of synergy or holism* (that the *whole is more than the sum of its parts*) which was noted already by [16, 17] but without stressing the irreducibility of holistic properties, see also [11] for a more detailed discussion.

2.4. What happened at the end of industrial civilization era

The technology of industrial civilization era was developed to such a degree that, for the first time in the history of human civilizations, on one hand it promised the possibility of freeing people from hard work, on the other hand has shown also the possibility of a total destruction of life on Earth. Fast and inexpensive travel, mass media and mobile communication, robotics and automation, landing on the Moon on one hand were counterbalanced by the specter of atomic bombs and nuclear death. Additionally, the overambitious uses of technology by political leaders mentioned in the introduction were aggravated by the fact that entire societies or social systems have became blinded by their seemingly unlimited power over nature given to them by the industrial technology, what has led to the large overexploitation of natural resources and severe degradation of natural environment. This has occurred especially in the communist system, where the official ideology stressed the social power of transforming the nature; this is occurring even today in the capitalist system, where the official ideology stresses that free market should determine the use of technology (e.g., in the issue of climate changes) as if the historical evidence of nature punishing too ambitious uses of technological abilities counted for nothing. In face of such controversies, it is no wonder that the ideological and intellectual crisis at the end of industrial civilization era has been very deep indeed.

This crisis, by the way, was even deepened by the erosion and then the fall of communism. The industrial civilization era had its basic great conflict. No matter what our ideological position, it must be objectively admitted that the big conflict of industrial civilization concerned the property of the fundamental productive resources of this era – the industrial assets. As soon as the industrial civilization era ended, the conflict became obsolete, which is what ended the importance of communist ideology. In other words, the mentioned above trend of dematerialization of work made obsolete the importance of the proletariat, which took away communism's legitimacy. Even if many intellectuals were disillusioned with communism, most were involved ideologically in this basic great conflict and the end of its importance deepened the intellectual crisis.

In epistemology, the beginning of the end of the *industrial era episteme* was marked already in 1953 by the seminal paper of W. V. Quine [18] which has shown that the logical empiricism is logically inconsistent itself, that all human knowledge is constructed. However, Quine insisted that this constructed knowledge should be evolutionary useful and thus should have *limited objectivity*, should *touch reality at least by its edges*. For diverse reasons, but possibly mostly because of the controversies and the crisis mentioned above, social science and humanities went much further to maintain that all knowledge is *intersubjective* – results from a discourse, is constructed, negotiated, relativist. This general belief has many variations. One thesis took the form of radical biological constructivism – see, e.g., [19, 20]: if all of knowledge is constructed by the human mind as a result of biological evolution, then the concept of truth is not necessary. This radical constructivism was in a sense supported by radical relativism, starting with radical sociology, mainly by the strong program of the Edinburgh school, see, e.g. [21, 22], but also by *post-existentialism* and *postmodernism* of, e.g., [12, 23, 24]. Opposite was a further development of humanistic rationalism: H.-G. Gadamer [25] stressed the value of truth as an essence of human self-realisation. However, humanistic sociology soon took an anti-rationalist and anti-technological position, initiated by H. Marcuse [26] with his concept of the single-dimensional man enslaved by the autonomous, dehumanizing force of technology; this position was followed essentially by all social scientists, including, e.g., J. Habermas [27].

In all these disputes, the emergence principle was essentially unnoticed and disregarded, while clearly reductionist arguments were used to deconstruct the concepts of truth and objectivity, trying to explain or even to deny the importance of such more complex concepts by the analysis of more primitive ones, such as money and power. But seen from the perspective of the emergence principle, truth and objectivity are concepts of a different layer of systemic complexity; they might be unattainable, but serve very clear purposes as ideals. Without trying to pursue objectivity, technology could not be successful, e.g., when trying to increase the reliability of transportation vehicles. Thus, these reductionist deconstruction attempts were in a sense *signs* of the end of a civilization era, when a general uncertainty of values results in a universal, playful anarchy.

The reader might infer that the above judgment is just an opinion of a technologist – but this already would indicate that a deep cultural rift has emerged between social sciences and technology towards the end of industrial civilization era. But we can quote here also the opinion of H. Kozakiewicz – a known Polish philosopher of sociology – who diagnoses [28] a crisis in sociology. She states that sociology is often called "the most general of social sciences". But she asks: *in what sense sociology is a science*? It is a science by tradition, since it started from positivistic beliefs of Comte that society can be described using methods similar to hard science. However, sociology itself revised these beliefs; the formulation that somebody uses "scientific methodology" means a strongly negative epithet for a sociologist today. A branch of sociology, sociology of science, including known trends of the second half of 20th century – the strong program of Edinburgh school [21, 22] with its stress of *interests*, the micro-constructivism (see, e.g., [29]) with its self-description of knowledge development, translation sociology (see, e.g., [30]) – all deny the possibility of objective epistemological explanations of science, and treat science only as a social discourse. What happens if we apply this approach to sociology itself? A paradox: *sociology is a social discourse about itself.*

3. The three separate cultures of technology, hard science and social science with humanities

3.1. Why separate cultural spheres?

We have indicated above that the cultural sphere of social sciences with humanities is different from the cultural sphere of technology, because they adhere to different values, have different *episteme*, use different concepts and language. But the same obviously concerns also social sciences and humanities versus basic, hard sciences. Less obvious is the fact that the same distinction concerns hard sciences versus technology. Some (social science) writers speak about *technoscience*; however, it is a great error, one of many signs of not fully understanding technology – while science and technology are obviously related, they differ essentially in their values and *episteme*. We shall discuss this difference later in more detail, but indicate its essence already here: while science ideals are true theories, technology ideals relate to the art of solving practical problems, even if the corresponding theory does not exist yet.

The anthropology of 20th century created a very useful principle of dealing with separate cultures: *you should never judge a foreign culture without trying to understand it well – otherwise you are just a cultural imperialist*. But then, what does postmodern sociology of science? By telling a hard scientist that he does not value truth, only power and money, it behaves like a communist activist coming to a priest and telling him that he does not value God, only power and money. By telling a technologist that his products enslave people, it behaves like telling an artist that his religious paintings enslave people – *essentially*, it behaves like a cultural imperialist. Thus, the *episteme* of hard sciences should be discussed, internally criticized and further developed by hard sciences themselves; the same concerns technology. The same concerns social sciences and humanities: until they overcome their own internal crisis, they should not expect that their opinions about hard science and about technology will be seriously attended to.

3.2. The dominant episteme of a cultural sphere and its limitations

If we adhered too closely to the principle described above, these three cultural spheres would become completely separated, which is neither possible nor desirable. Therefore, intercultural understanding should be promoted; with this aim, we present here notes about the dominant episteme of each culture. In order to foster intercultural understanding, but also to indicate the limitations of each episteme, we shall also use metaphors when describing the differences between these cultural spheres.

Even if a hard scientist knows that all knowledge is constructed and there are no absolute truth and objectivity, he believes that scientific theories are *laws of nature discovered by humans* rather than *models of knowledge created by humans*. He values truth and objectivity as ultimate ideals; metaphorically, *hard scientist resembles a priest*. However, a modern hard scientist does not value tradition very much; he is willing to abandon old theories, if new theories are closer to the ideals of truth and objectivity.

A technologist is much more relativist in his episteme, he readily agrees that scientific theories are models of knowledge – because he uses such theories in solving practical problems, and if he has several competing theories, he simply compares their usefulness. If he does not have scientific theories to rely upon, he will not agree to wait until such theories are created[1], but will try to solve the problem anyway using his own creativity. Metaphorically, a *technologist resembles an artist*. He also values tradition like an artist does: an old car is beautiful and, if well cared about, can become a classic.

A postmodern social scientist or a soft scientist (e.g., historian[2]) believes that all knowledge is *intersubjective*, results from a social discourse, is constructed, negotiated, relativist. There are traps in such episteme, it would not stand up against a serious internal, Kantian-type critique, as indicated by the examples given by Kozakiewicz; but this is

[1] This corresponds also to personal experiences of the author of this text, see, e.g., [11].

[2] Again from personal experience of his family and friends, the author knows well that not all historians are postmodernist and relativist.

a sign of an internal crisis that must be overcome by social and soft sciences themselves. Metaphorically, a *postmodern social or soft scientist resembles a journalist*: anything goes as long it is interesting.

3.3. Is a serious philosophy of technology possible without consulting technologists?

If technology corresponds today to a different cultural sphere, we must give a strongly negative answer to such a question. This not only results from the principles of cultural anthropology; it is simply a common sense. It is just too dangerous not to understand technology, if it gives us today not only the power to transform totally our lives, but also to destroy life on Earth – not only by an inappropriate use of nuclear energy, but also, e.g., by an inappropriate use of genetic engineering, or even robotic technology. Postmodern social and soft sciences will not able to understand technology until they overcome their internal crisis, achieving a synthesis of intersubjectivity and objectivity. Hard sciences will continue to see technology as a mere application of their theories. All this creates an extremely dangerous situation; the perception of this terrifying danger only deepens when we study the contemporary philosophy of technology.

4. The views of philosophy of technology

4.1. The general impression of a technologist

The general impression from reading contemporary publications on philosophy of technology is that they do not understand technology, even do not actually investigate technology – they present only slightly modified views on philosophy of science, treating technology as a mere application of science – and often represent anti-technological attitudes, by propagating the mistaken opinion about technology as an autonomous, dehumanizing, enslaving force. For example, an excellent – at least, in its breadth – review of old and current writings on philosophy of technology [31] includes 55 papers, of which 14 at the beginning the volume are on philosophy of science and the first of papers starting the actual discussion on philosophy of technology [32] is based on the assumption that technology is just an application of the theories of hard science. The most basic question of ethics of technology is addressed by a paper [33] that counterposes technology and ethics: technology is seen as not only an autonomous and dehumanizing force, but also an unethical force. This type of anti-technological flavor can be seen in most of remaining papers; of the final seven papers, only one [34] is free of such flavor, but it is immediately followed by a paper criticizing the previous one and presenting technology as the opiate of intellectuals [35]. And in all 55 papers, *there is no paper written by a technologist*.

4.2. A few acceptable views

Nevertheless, few papers present views that are acceptable to technologists; notably, they are the ones most discussed or criticized by other papers.

The most close to the perception of a technologist what he truly does is the fundamental analysis of M. Heidegger in *Die Technik und die Kehre* [36], repeated in [31] in somewhat unfortunate translation *The Question Concerning Technology*; thus, we use somewhat more adequate translation as a part of the title of this paper. *The Question Concerning Technology* is commented upon in [31] by a number of other papers, all trying to show either that Heidegger perceived technology as an autonomous, dangerous force or that he was not critical enough of technology; neither of this papers interprets Heidegger in a way that a technologist would. The problem of the difficulty and diversity of interpretations relates to the fact that Heidegger was a poet at heart, playing with words to achieve empathy and *essential truth* as opposed to a *correct understanding*. Possibly because of that, he empathically understood the artistic nature of technology; we comment on this in more detail later.

There are few other papers in [31] that indicate an understanding of the (Heideggerian) *essence* of technology; an important one by E. G. Mesthene [34] is devoted to the social impact of technological change. We quote here some of his sentences important for further analysis.

At its best, then, technology is nothing if not liberating. Yet many fear it increasingly as enslaving, degrading, and destructive of man's most cherished values. It is important to note that this is so, and to try to understand why.

Unfortunately, further analysis given by Mesthene is not conclusive, because he does not make a clear enough distinction between technology proper and the socio-economic system exploiting technology, which we shall also discuss in more detail later.

There are also other writings on philosophy of technology – curiously, not represented in [31] – that show a (Heideggerian) correct understanding of technology; they are dealing mostly with the question whether the concept of a Kuhnian revolution in science is applicable also to technology[3], see [37], and define technology as a practical problem-solving activity, which is certainly correct if still not fully essential.

4.3. The dangers of mistaken diagnosis

There is, however, a grave danger in the mistaken diagnosis that technology is an autonomous, enslaving and degrading force: *a wrong diagnosis cannot help to cure the illness*. Technologists perceive the diagnosis as a sign of misunderstanding, thus disregard it; social scientists have found

[3]It is interesting that these writings question the applicability of the Kuhnian concepts to technology, which is consistent with the perception of the author of this text that technology is closer to the Popperian concept of *falsification* than to the Kuhnian concept of *paradigm*.

a scapegoat to put the blame on, thus do not reflect on their own responsibility. But, as we shall show later, both sides should feel responsible.

We should note that technologists perceive the misunderstanding by social sciences also in other cases. In systems research, there is the example of debate between soft systems thinking and hard systems thinking, in particular, the issue of soft systems methodology (SSM) [38]. SSM stresses listing diverse perspectives, including so-called *Weltanschauungen*, *problem owners*, and following open debate representing these diverse perspectives. Actually, when seen from a different perspective, that of hard mathematical model building, SSM (if limited to its systemic core) must be also evaluated as an excellent approach, consistent with the lessons derived from the art of engineering system modeling even much earlier. More doubts arise when we consider not the systemic core, but the paradigmatic motivation of SSM. The SSM is presented by P. Checkland in [38] as a general method, applicable in interdisciplinary situations; but a sign of misunderstanding is the opinion that *soft systems thinking* is broader and includes *hard system thinking* as defined there. But then, should not SSM be also applicable to itself? It includes two *Weltanschauungen: hard and soft*; thus the problem owners of hard Weltanschauung should have the right to define their own perspective. However, hard systems practitioners never agreed with the definition of hard systems thinking given by Checkland. He defines hard systems thinking as the belief in the statement of [39] that *all problems ultimately reduce to the evaluation of the efficiency of alternative means for a designated set of objectives*. On the other hand, hard system technological practitioners say *no, they are hard because they use hard mathematical modelling and computations, but for diverse aims, including technology creation, when they often do not know what objectives they will achieve.* As a result of such differences in episteme, hard and soft systems researchers simply do not understand each other.

5. What technology is and what it is not

5.1. The definition of technology by Heidegger as understood by a technologist

M. Heidegger came closest to the *essence* of technology by stressing several essential facts:

- technology is obviously means of transforming nature and also obviously a human activity;
- *technology is an art of solving practical problems*, not an application of abstract theory;
- in its *essence*, the technological act of creation is an act of *revealing the truth* out of many possibilities offered by nature.

We can thus interpret Heidegger that *humans cannot escape creating technology*, similarly as a child cannot escape playing with blocks. It is thus our basic, even defining characteristics, an intrinsic human trait.

No matter how we define humanity, we would stop to be human if we stopped technology creation.

5.2. The warnings of Heidegger as understood by a technologist

M. Heidegger also perceived that technology in industrial civilization changed qualitatively when compared to technology of older times by offering humans almost complete control over nature. However, such control, when exercised without reflection and restraint, might threaten the very essence of human being. This warning was correct, we learned later at much cost that our control over nature is never complete and that unrestrained control over nature is very dangerous for us.

But Heidegger never condemned technology in itself as an autonomous, alienating and enslaving force; this condemnation came later, started in social sciences by Marcuse [26]. Heidegger writes (about the results of perception of a complete control over nature) explicitly: *Meanwhile … man exalts himself and postures as the lord of the earth*. Thus, though Heidegger did not make a precise distinction here, *his warning concerns not technology proper, but the social use of technology* – and, assuming that Marcuse has read and understood Heidegger, his condemnation of technology must be read as shifting the blame.

Nevertheless, a technologist must read a lesson for himself out of these controversies: *he must be careful what technologies he puts at social disposal, because the socio-economic system might use them without restraints and the blame will be put later not on the system and social scientists apparently responsible for such systems, only on technology*.

5.3. The sovereign though not autonomous position of technology

We start with a definition of technology acceptable to technologists, distinguishing *technology proper* from *the system of socio-economic applications of technology*.

Technology proper is a basic human trait that concentrates on the creation of artifacts needed for humanity in dealing with nature. It presupposes some human intervention in nature, but can also serve the goal of limiting such intervention to the necessary scale. It is essentially a truth revealing, creative activity, thus it is similar to arts. It is also, for the most part, a problem solving activity, concentrating on solving practical problems.

Thus, it uses the results of basic sciences, if they are available; if they are not, technology proposes its own solutions, often promoting this way quite new concepts assimilated later by basic or social sciences. It is not an autonomous force, because it depends on all other human activities and influences them in return. It is, how-

ever, sovereign, in a similar sense as arts are sovereign human activities. Autonomous forces can be found in the socio-economic system of applications of technology proper.

The second part of this definition requires some discussion which will be given in the next sections.

5.4. The reverse relation of science and technology

It happens actually very often that technological solutions precede the developments of science.

The first obvious example is the technological development of a wheel. The mathematical concepts of a circle and that of actual infinity stem from this technological development: a wheelwright constructs a wheel as a polygonal structure, slowly increasing the number of sides of the polygon by cutting consecutive angles, until an approximate circle and an (approximately) smooth wheel is achieved[4]. Some philosophers of mathematics [40, 41] show that most of ancient mathematics before Greek times was technology-oriented and used not the concept of a formal proof, only that of pragmatic demonstration.

Another example, well known in the philosophy of science [37] is the impact of the technological development of a telescope on astronomy and Galileo's findings.

But there are also modern examples. The improvement of a steam engine by Watt was a mechanical control engineering feedback system for stabilizing the rotational speed of the engine (before Watt, the rotational speed was unstable and steam engines tended to explode). This not only started the industrial civilization era, it also motivated several lines of scientific enquiry. One was that of stability of dynamic systems, started by such great minds as W. Kelvin-Thomson and J. C. Maxwell, see [42, 43], leading eventually to diverse aspects of nonlinear systems dynamics and to the theory of deterministic chaos, thus finally to the emergence principle, see [11, 13, 44]. Another was the extremely important concept of feedback, upon which we comment later, attributed incorrectly by social scientists – see, e.g., [45] – to N. Wiener [46]; actually developed much earlier in telecommunications by H. Nyquist [47], V. Bush (the creator of the first analog computer, earlier than digital computers) [48], and many others. Equally important was actually the concept of a system[5], attributed by social science first to Comte, then – when Comtian positivism came under critique – to Wiener and Bertalanfy [16]; but practical systems engineering developed in technology much earlier, since Watt, and has lead eventually to the most developed technological systems today – to computer networks.

[4]A turning lathe making the wheel really smooth was invented much later.

[5]The concept of a system is extremely important too, but possibly not more important than the concept of feedback; without feedback we would not have robotics, without robotics we could not transit to knowledge-based economy where human labor as a basic productive input is substituted by human knowledge.

Less known is the example of a quasi-random number generator in digital computers. Developed already in 1950s, preceding the development of the theory of deterministic chaos starting in 1960s, the principle of such a generator exemplifies in fact the basic principles of a strange attractor: take a dynamic system with strong nonlinearity and include in it a sufficiently strong negative feedback to bring it close to instability. In the quasi-random generator, we use recourse, repetition instead of dynamics and feedback and add a strong nonlinearity. The simplest example is: take a digital number, square it, cut a quarter of its highest bits and a quarter of its lowest bits, and repeat the procedure. The resulting sequence of digital numbers is in fact periodic, but with a very long period and behaving meanwhile as if it were random. Thus, technological "applications" of deterministic chaos theory appeared earlier than the theory.

There are many other such examples in the recent history of information science and technology. The development of *data warehousing* in early 1990s was caused by economic and technological necessities, independent from existing theories; but it in a sense surprised information science specialists that concentrated before on relational data bases, and is leading today to new advancements in information science, etc.

5.5. Two positive feedback loops

Thus, how do hard, basic science and technology depend on each other? As in many questions of human development, they influence each other through the intellectual heritage of humanity, the *third world* of K. Popper, see [11, 49]. But this influence forms a *positive feedback loop*, see Fig. 1; technological development stimulates basic science, scientific theories are applied technologically.

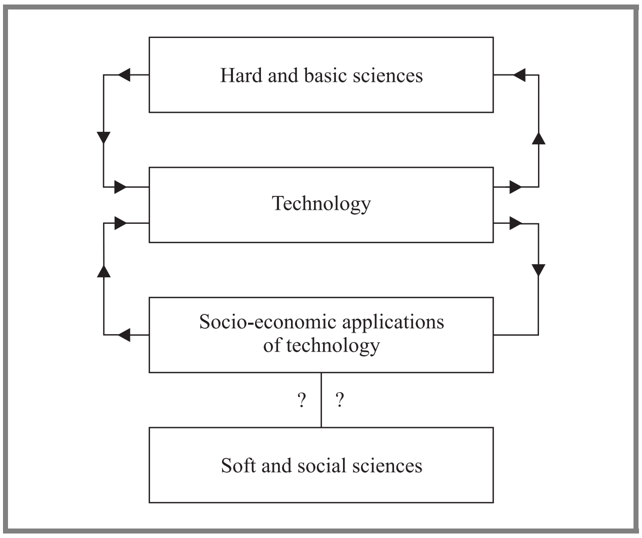

Fig. 1. Two positive feedback loops.

We must recall that *feedback* – the circular impact of the time-stream of results of an action on its time-stream of causes – was used by Watt in a *negative feedback loop*.

Feedback can be of two types: *positive feedback* when the results circularly support their causes, which results in a fast development, like a growing avalanche, and *negative feedback* when the results circularly counteract their causes, which results in an actually positive effect of stabilization (for example, the stabilization of human body temperature is based on negative feedback). The concept of feedback essentially changed our understanding of the cause and effect relationship, resolving paradoxes of circular arguments in logic, though it must be understood that such paradoxes can be resolved only by dynamic, not static reasoning and models.

But the positive feedback loop between technology and science works relatively slowly: technological stimulations are analyzed by science with much delay, technology also does not reply instantly to new scientific theories.

The second positive feedback loop is between technology and the systems of its socio-economic applications. The distinction between technology proper and its socio-economic applications is not stressed sufficiently by social sciences, in particular by postmodern philosophy of technology, though it should be obvious for at least two reasons. The first is that technologists often work on a technological problem quite long (e.g., almost fifty years in the case of digital television) before their results are broadly socially applied. The second is simple: *technologists do not make much money, technology brokers do*, similarly as art brokers make more money than artists. By *technology brokers* we understand here entrepreneurs, managers, bankers, etc., all our socio-economic systems turn around applications of technology. If a technological product or service, such as mobile telephony, produces much revenue, then more money is available for its further technological development; this leads to truly avalanche-like processes of social adoption of technological hits.

But these processes have also strange dynamic properties, socio-economic acceptance of novelties is slow, there is usually a large delay between purely technological possibility and the start of an avalanche of its broad socio-economic applications (not only in the case of digital television; this delay time amounted also to almost 50 years in the case of cellular telephony). This delay has many causes; one is the necessity to develop such technological versions that are inexpensive enough for an average customer; another is an initial social distrust turning into a blind social fascination once a technological hit becomes fashionable. For this reason, once it starts to work, the second positive feedback loop is much stronger and faster than the first one. *This blind social fascination is actually the autonomous force incorrectly attributed by social philosophy to technology proper*, it is precisely the source of the Heideggerian danger that *man exalts himself and postures as the lord of the earth*. For example: how many people are aware that mobile telephony makes it very difficult to practice radio-astronomy from Earth surface, that it is the reason of moving radio-telescopes into cosmic space? And this is a relatively modest adverse effect; what if an avalanche-like adoption of a technological hit would result in truly disastrous effects? After all, a nuclear power station is also based on avalanche-like processes that must be carefully controlled – by negative feedback systems of control engineering – to be safe; but if such systems fail (or are tampered with for fun by irresponsible people, like in the Chernobyl case), the disaster can have no limits.

The answer to the question of Mesthene: why it is so that many people perceive technology as an alienating force, enslaving, degrading, and destructive of man's most cherished values, might be the following: the essential reason of it is the intuitive perception of such danger of a social infatuation with technology leading to avalanche-like process of social adoption of technological hits with diverse resulting threats and possible catastrophic results.

Being intuitive, the perception needs not to be rationally correct and the diagnosis can be wrong, see the discussion of a rational theory of intuition in [11]; in order to obtain correct answers and useful diagnosis, we must analyze it critically. Thus, we encounter crucial questions here:

1. What mechanisms limit and stabilize the avalanche-like processes of socio-economic adoption of technological hits?
2. Who is responsible for overseeing that these mechanisms work effectively?

The one mechanism that at least safely prevents any economic excesses is the market economy; people tried to replace market by human intervention in the communist system without success. However, it is only a robust mechanism, it does not solve many problems and creates some new ones. For example, because knowledge-based economy sharply decreases marginal production costs, prices on high technology markets have today no relation to (actually, are over hundred times higher than) marginal production costs; therefore, an ideal, free market simply does not work in knowledge-based economy, and a monopolistic or oligopolistic behavior is typical, see, e.g., [50]. Who will watch over such global oligopolistic markets?

As to the responsibility, obviously it should be borne first by the *technology brokers*. However, to be effective on the market, they must be motivated by profit, let us only hope that the motivation will be tempered by ethics. Ethics results from education; *who educates technology brokers*? Not technologists proper, but social and soft scientists. They should not only educate well technology brokers ethically, but also help them to understand their future jobs by analyzing in detail the mechanisms of social demand for technology, of infatuation with technological hits, together with their dangers.

Thus, the ultimate responsibility for socio-economic applications of technology, for overseeing the effective limitations of blind social fascination with technological hits lies at soft and social sciences.

Unfortunately, they do not perform well in this respect, prefer to put the blame on technology proper, undistinguished from the system of its socio-economic applications and deplored by them as a technocratic tool of enslavement by promoting the functionalist view of the world. This is indicated by the question marks in Fig. 1: while the role of hard, basic sciences and technology proper versus its socio-economic applications is clear, soft and social sciences do not seem to fullfil nor even understand their role.

This does not mean that technology proper is not co-responsible and should not at least try to work together with social scientists on limiting such dangers. However, a technologist is usually very conscious of ethical dangers, carefully considers possible future impacts of technology developed by him – and even if it is not the case, he must be careful because he knows that the blame for any possible misfortunes and misapplications will be put on him. On the other hand, we cannot expect that the responsibility of technologists will prevent all misapplications of technology. One reason is that human creativity of misapplications is boundless (*against stupidity, the gods themselves contend in vain*). Another is more serious: the very nature of knowledge-based economy will give human societies almost boundless possibilities to choose from diverse technological options.

6. What will be the technology of the knowledge era (postmodern technology?)

6.1. The character of technology in the knowledge era

We must ask today a renewed version of Heidegger's question about *die Kehre* (the change of the character of technology, in his case in the industrial era as compared to earlier times). The question is: *in what qualitative aspect will the technology of knowledge civilization era differ from the technology of industrial civilization era*? A tentative answer proposed as the main conclusion of the paper is:

The technology of knowledge civilization era will differ in complexity, by proposing an unlimited number of diversified technological possibilities, oriented toward not only products, but also services, including such services as creativity support, and only a small part of these possibilities will be actually accepted for economic and social use.

We could call it *postmodern technology*, but the change will be deeper than the intellectual fad of postmodernism indicating the end of industrial civilization. We shall illustrate this answer by some examples.

6.2. Some examples of technology of the knowledge era

One of the most important possibilities brought by the technology of the knowledge era will *be the change of the character of recording of the intellectual heritage of humanity.* In the last two civilization eras – the preindustrial and the industrial – the dominant medium of recording the human heritage were printed books. Information technology will make soon possible full multimedia recording of human heritage; in other words, instead of a book we will have an electronic record including film, music, interactive exercises and virtual laboratories. Imagine today the possibility of listening to a lecture of Kant or Einstein recorded in such a way; but the change goes beyond such possibilities. This change will have impacts exceeding the impacts of Gutenberg printing technology; the nature of our civilization will change, multimedia recording will stronger support the intergenerational transmission of intuitive knowledge and of humanity intuitive heritage, will enable more effective distant and electronic education, see [11] for more detailed discussions.

Another possibility concerns *ambient intelligence*, called also AmI in Europe, either *ubiquitous* (omnipresent) *computing* or *wireless sensor network* in the United States, *intelligent home* or *building* or *yaoyorozu*[6] in Japan. There is no doubt that the number of possible ways of helping people by using computer intelligence dispersed in sensors and processors in our ambient habitat – at homes, in offices, in shops, in vehicles, etc. – is endless and that people will buy such technology once it is truly ubiquitous and inexpensive. However, there are also grave social threats related to this technology – not immanent in the technology, but in the way people might use it. Ambient intelligence requires electronic identification of a person, say, when entering his room. What would prevent overzealous police from using this technology as a way of realizing the concept of a *Big Brother*? Ambient intelligence means also ubiquitous robotization; what would constrain too inventive criminals from using robotic squads to break into banks or as invincible bodyguards?

We will mention here only one more of the endless possibilities of future technology of the knowledge civilization era. *Computerized decision support*, developed towards the end of industrial civilization, can be developed further into *computerized creativity support*, helping in the creation of knowledge and technology. For this purpose, we must understand better knowledge creation processes – not on grand historical scale, such as in the theories of T. Kuhn [51] and many philosophers following his example, but on a micro scale, for today and tomorrow. There are many such micro-theories of knowledge creation emerging in the last decade of the 20th century and in the first decade of the 21st; the book *Creative Space* [11] was motivated precisely by the need of integrating such theories.

6.3. New warnings: what we must be careful about

In all these possibilities, complexity and diversity, there is also a general danger and we must thus also repeat a renewed version of Heidegger's warning. As already perceived by Heidegger, the danger lies not in technology proper, but in us, humans fascinated by the possibilities

[6] Eight million Shinto gods, implying omnipresence.

of technology and not fully understanding the threats of such fascination.

In particular, the seemingly unbounded technological possibilities might suggest to people – particularly to *technology brokers* – that human intellectual heritage is rich and boundless enough to privatize it without restraint. Already today we observe many attempts of knowledge privatization. However, similarly as the unbounded privatization of natural resources in the industrial civilization era has led to grave pollution of natural environment, unbounded privatization of intellectual heritage will lead to pollution of this heritage – what we already observe, e.g., on drug markets. Thus, the modified Heideggerian warning is:

In the industrial civilization era, people became blinded by their seemingly unlimited power over nature given to them by the industrial technology, what has led to the large overexploitation of natural resources and frequent degradation of natural environment. We must take care in the knowledge civilization era not to become blinded by the seemingly unlimited possibilities of products and services offered by technology, in particular – we must take care to preserve our intellectual environment, the intellectual heritage of humanity.

7. Conclusions

There is no doubt that *technology contributed essentially to the change of civilization eras, from the industrial to information and knowledge civilization* observed now. The change has a social character, but *resulted from technology, from computer networks making possible the wide social use of information technology*. Technology brought also the dematerialization of work: automation, computerization and robotization have relieved humans from most of heavy work and created realistic conditions for the equality of women.

This was desired by many social thinkers, but, ironically, they usually – starting with [26] – condemned technology as an autonomous, alienating, de-humanizing force, as a technocratic tool of enslavement or functionalist view of the world. Similarly, technological objectivism was condemned as an outdated form of positivistic thinking; this paradigmatic attitude was strongest in postmodernist and constructivist approaches, but it has been paradigmatically upheld by sociology in general. This condemnation is still the prevailing reason for the lack of understanding of technology by sociology.

Technology, on the other hand, is motivated by the joy of creation (as observed by Heidegger, the old Greek word *techne* meant creative arts and crafts). To be successful in such creation, technology requires *informed objectivity*. Technologists understand that there is no absolute knowledge and truth, nor absolute measurement precision – but they must try to be as objective as possible, must not overlook inconvenient or unpopular information, since such neglect can result in a technical failure of systems they construct.

Technological *informed objectivism* is not the positivistic belief that ultimate truth exists based on empirical facts, since many technologists admit that we create knowledge and cannot attain absolute truth, but it is the conviction that objectivity and closeness to empirical facts are useful goals that have always helped in the successful construction of technological artifacts, even if these goals are ultimately unattainable. Social science seems not to be able to understand this distinct culture of technologists and condemns it without understanding, which is equivalent to cultural imperialism.

Even more pronounced is the misunderstanding of technology in postmodern social philosophy. Philosophy could not come to a synthesis of opinions about the role of technology, even if a very deep analysis of the essence of technology was given by Heidegger. However, we need an acceptable definition of technology at the beginning of knowledge civilization era and should agree that such *definition of technology for a general reflection must come from problem owners*, i.e., *technologists*, in particular from technologically oriented systems science.

Such a definition is proposed in this paper; it stresses that technology is a basic human trait that concentrates on the creation of artifacts needed for humanity in dealing with nature. We cannot stop being technologically creative without stopping being human. Technology presupposes some human intervention in nature, but can also serve the goal of limiting such intervention to the necessary scale. As suggested by Heidegger, *technology is, in its essence, a truth revealing, creative activity, thus it is similar to arts*. It is also, for the most part, *a problem solving activity*, concentrating on solving practical problems – although recently, like basic science, it is involved also in *searching for new perspectives*.

The relation of *technology and basic science forms a positive feedback loop*: technology poses new problems and concepts for basic science, basic science produces results that might be later applied in technology – but *technology is sovereign in this loop*, proceeds to find solutions even without having the input of basic sciences. In this sense, the technological development of the wheel motivated the development of mathematics together with the concept of actual infinity, which in turn helped in further development of technology. There are many other examples of such reverse relationship between hard science and technology.

Even more important is the *second positive feedback loop between technology proper and the system of its socio-economic applications*. These applications are managed by *technology brokers*, i.e., entrepreneurs, managers, bankers, etc., all our socio-economic systems turn around applications of technology. This second feedback loop brings about most social and economic results of technology, but at the same time it may create grave dangers. This is because processes of socio-economic adoption of technological novelties in this feedback loop are avalanche-like; such processes are known, e.g., in nuclear reactors, where they must be controlled and stabilized by additional negative feedbacks. If this additional stabilization does not work properly, disasters might occur. An intuitive perception of the threat of such disasters is the essential reason for condemnation of technology by social sciences and humanities. But this intuitive perception does not give a correct diagnosis.

In socio-economic adoption of technology, the stabilization of avalanche-like processes is achieved by market mechanism, but this mechanism on high technology markets does not function ideally, has a tendency to promote oligopolies and monopolies. Moreover, market obviously does not resolve ethical issues of technology adoption. Since technology brokers are educated mostly by soft and social sciences, the ultimate responsibility for socio-economic applications of technology, for overseeing the effective limitations of blind social fascination with technology lies also at soft and social sciences.

We are repeating in this paper, in a sense and in new conditions, the analysis presented by Heidegger in *Die Technik und die Kehre*, coming to the main conclusion that the technology of knowledge civilization era will differ from that of industrial era in complexity, by proposing an unlimited number of diversified technological possibilities, oriented toward not only products, but also services, including such services as creativity support.

We also are repeating and strengthening the Heideggerian warning about human fascination with technological possibilities: *we must take care in the knowledge civilization era not to become blinded by the seemingly unlimited possibilities of products and services offered by technology*, in particular – we must take care to preserve our intellectual environment, the intellectual heritage of humanity.

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