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15, avenue de Ségur,
75007 Paris, France.
Tel (Fr) 01 45 51 26 07 - (Int.) +33 1 45 51 26 07
Fax (Fr) 01 45 51 26 32- (Int.) +33 1 45 51 26 32
E-mail: ijdst@europia.org
http://www.europia.org/ijdst

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Cyber-physical Systems as a Cultural Phenomenon

Ilya Levin[1]

[1] Tel Aviv University, Israel, Email: ilia1@post.tau.ac.il

The paper deals with signs of the emerging digital society, which is considered to bring a new form of culture – Digital culture. A number of features of Digital culture are discussed. One of such features – emergence of cyber-physical systems. It is shown that characteristics of the cyber-physical systems correspond to symptoms of the digital society: blurring of distinctions between reality and virtuality; between people, machines and nature; reversal from scarcity to abundance of information; shifting from primacy of entities to primacy of interactions. These symptoms, being manifested in characteristics of the cyber-physical systems, define a specific character of the technological culture of digital society and allow predicting its tendencies.

Keywords: digital society, culture, cyber-physical systems, personal identity online, socially aware design

1 Introduction

Our society is moving to the Digital era, which is considered the fourth revolution in the mankind history [3] . The first, Copernicus revolution changed the concept about the mankind being the centre of the Universe. The second revolution (Darwin's revolution) led to understanding that a human is not the unique creation but a part of the nature, being just a result of the animals' evolution. The third revolution (revolution of Freud) cancelled the conviction that consciousness of a human being is fully predictable, i.e., that we can always understand what is going on in the human mind. Today, we feel the advent of the fourth, digital revolution. The digital revolution, similarly to the three previous revolutions, relates to very fundamental principles accepted by a human being. It changes the peoples' understanding of their place in the world from being just a part of the nature, to being also part of the artificial world created by them. The people start perceiving themselves as "the kind of informational organisms that live, flourish, interact, not as stand-alone entities but as networked agents in a world that is made of information".

The main distinctive feature of the fourth revolution is recognition by people of existence of *infosphere*, and self-recognition by the people as informational organisms (inforgs). Quite a short time ago the term "infosphere" was roughly corresponded to cyberspace, extended by traditional off-line and analogue souses of information. This infosphere was perceived the totality of informational agents and objects, services, relations, processes as well as the space within which they interact [2].

The cyberspace was perceived as a new, comfortable kind of communication technology. In particular, even an interface (browser), which converted the Internet into the worldwide web, was perceived (and is often perceived even now) only as hypertext, and just being more advanced and more convenient to use than a regular book. Such a perception of cyberspace corresponds to understanding it as just one technological achievement. Actually, some years ago it was difficult to argue against such a position, since indeed, the Internet consisted of a plurality of interconnected web pages and, globally, served as a huge storage of information.

However, this situation has radically changed some years ago, with the emergence of the new Internet technologies, which are widely known under the name Web 2.0. At that time, a new understanding of cyberspace appeared, whereby its meaning differs from the pragmatic perception of cyberspace as a tool. Cyberspace has become a new, virtual reality, i.e. it appears that now our lives are linked to a prolonged and meaningful existence in cyberspace. As a result, ~~a~~ mentioned new understanding of the cyberspace has appeared. We have associated the cyberspace with our second, virtual reality, which is an extension of the traditional one.

Nevertheless, today we have come to a more general and more precise definition of the infosphere and its interrelation with the concepts of cyberspace and Internet. By separating the informational life of humans from their real life, we miss one of the most important phenomena of the digital revolution – perceiving ourselves as inforgs, which interact with information artefacts. The wide distribution and use of various smart devices, the distribution of Internet of Things (IoT) etc. demonstrate the limited character of old definitions of infosphere.

According to Floridi, "Infosphere is synonymous with the whole reality. It is a way of referring to what there is, by adopting an informational perspective. This means equating the Infosphere to what philosophers call Being. Infosphere is a very powerful concept. It means having a unified vocabulary to talk about DNA, computers, physical particles, avatars, social environments, humans, companies or webbots as agents, interactions as forms of communication, biosphere, ecosphere and cyberspace, and so forth".

In the present paper, we suggest to consider informational artefacts as cyber-physical systems (CPS), which are a new type of systems. On one hand, CPS is a result of evolution of technical systems, on the other hand – appearance and development of CPS is a symptom/feature of a new digital society where borders between people, artefacts and nature are blurring. In this work, we also present and analyse other symptoms of the digital society and illustrate such other symptoms by various characteristics of CPS.

We analyse the digital society as a cultural phenomenon. Cultural space of any society is formed on the basis of three faces of culture: spiritual, social, and scientific/technological. We show that in the digital society, the main phenomenon of its spiritual culture is a so-called online personality. In turn, the social culture of the digital society can be defined by the enhanced social awareness.

We consider that the main finding of the present work is recognition of CPS as one of the main factors affecting the digital society. We see that emergence of CPS affects the technological culture of society. Moreover, the very nature of CPS having deep interrelations with a human personality and its social behaviour has to be considered as a common phenomenon of the digital culture.

The paper is organized as follows. The culture of digital society is discussed in Section 2. Symptoms of the digital society and their manifestation in cyber-physical systems are presented in Section 3. Section 4 concludes the paper.

2 Culture of digital society

2.1 Three-dimensional space of culture

One well-established presentation of human culture is in the form of so-called "three-dimensional space of culture", which is defined by three axes: a knowledge axis, a regulations axis, and a values axis [6]. These axes are formed between three plains corresponding to three faces of human culture: spiritual, social, and science-technological.

The symptoms of transition into a digital society are reflected in new trends of a comprehensive reality. We will consider these trends as respectively corresponding to the above three faces of culture.

The spiritual culture of digital society (and of any other society) is sensitive to a human personality, to its self-identification, and to the perception of the person-society interaction. In the digital society, the characteristics are manifested by the appearance of the networked personality, a so-called Personal Identity Online (PIO) [1, 16].

Taking into account the role of the social component of culture in a digital society, we believe that the main feature of the social culture in digital era can be formulated as *enhanced social awareness*. This enhanced awareness infiltrates into all sides of life, but there is a new perception by humans of two socially meaningful concepts: a) the Social Media as the main environment of forming the social consciousness and b) digital artefacts as socially behaving entities.

The *science-technological* culture of the digital society is most sensitive to the two separate phenomena. The first of them relates to the scientific culture, and the second – to the technological one. The scientific culture (the part of science-technological culture) is affected by the abundance of data and to the free access to knowledge, which is inherent in the digital era. From the era of Enlightenment, the idea of encyclopaedic knowledge was constantly accompanied by both the scientific research and the educational system. In turn, the technological culture of digital society, which is oriented on designing informational artefacts, has its own trend manifested by emerging Cyber-Physical Systems (CPS).

Summarizing, we can claim that the main trends in the culture of digital society are: Online personality, Enhanced Social Awareness, and Cyber-Physical Systems [10].

Note that the above three trends rather define development directions of the digital society culture, than the culture *per se.* It is impossible to accurately define the digital culture today, as well as to forecast what it will look like in the future.

Presently, we will try: a) to imagine a society where Enhanced Social Awareness dominates b) to understand what is the characteristic feature of the spiritual life of networked personalities, and c) to forecast how the abundance of information and Cyber-physical Systems will affect the development of science and technology. Definitions of the main cultural trends of digital society are presented in Table 1.

Table 1 Definitions of cultural trends of digital society

Face of culture	**Phenomena**	**Neutral definition**	**Value-laden definition**
Spiritual Culture	On-line personality	Ability of Websites to distinguish one individual from another	Personality formed in Network
Social Culture	Social Media	Use of Web apps supporting creation of user-generated content	New way of forming social consciousness
	Social Artefacts	Enhanced communicative features of artefacts	Perception of digital artefacts as socially behaving entities
Science and Technological Culture	Data-intensive Science	Data growing faster than technology	Fourth paradigm of science
	Cyber-Physical Systems	Systems combining technologies of computing, networking and information, and of physical artefacts	Artificial inforgs, inhabiting infosphere

Columns of the table corresponds to: a specific face of culture; the name of the phenomenon defining the corresponding face of culture; two different definitions of the corresponding phenomenon: (1) neutral, which is traditional, technology-oriented, and (2) valued-laden and humanitarian, which correspond to the spirit of the present paper.

Since each of the mentioned trends (phenomena) corresponds to specific faces of culture, they may be schematically mapped into the "space of digital culture" (Figure 1).

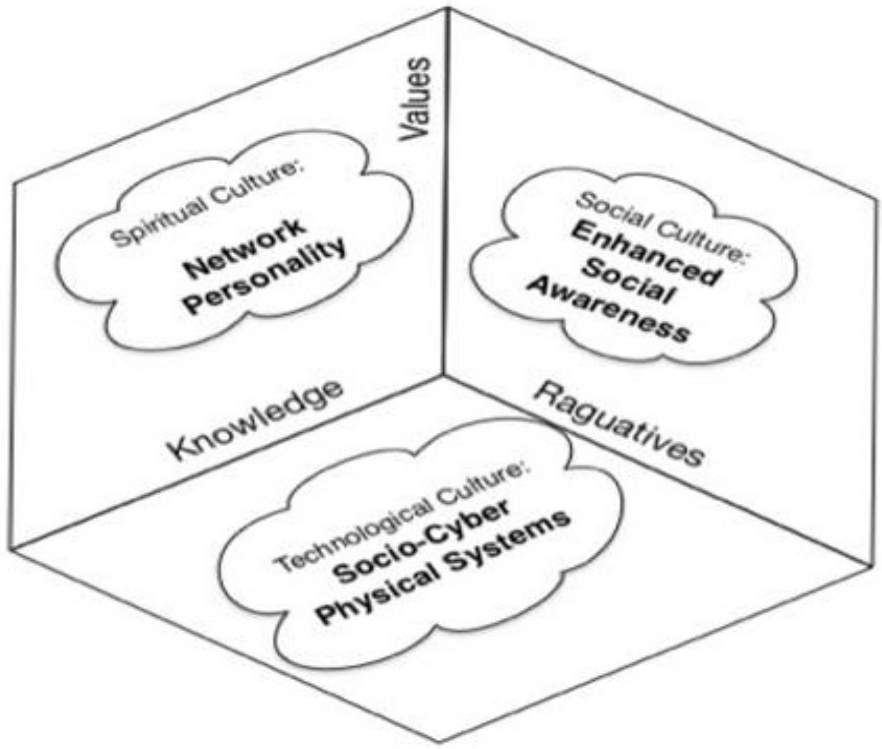

Figure 1 Space of digital culture

We argue that that above-mentioned trends (phenomena) form the cultural space of the digital society. In next sections, we will discuss each of the trends.

2.2 On-line personality - factor of spiritual culture

Technologically, the On-line Personality relates to the network's ability to recognize personalities inhabiting it. Recognition of a personality by the network creates a situation, in which "the recognized person" begins to perceive network content as corresponding to his/her personal features. As a result, each person "sees" the network at a different individual angle, in other words - each person forms his/her subjective opinion about a specific topic.

Simultaneously, a person forms his/her own personality in the network. Forming a network personality takes place in a complex and multilateral interaction with other network personalities, informational artefacts and network communities. Note that a so-called "on-line personality" may differ from the corresponding traditional (off-line) personality. Forms and special features associated with creation of a digital (network) personality have not yet been studied. However, it is already obvious that personification of an inhabited network directly affects one of the most fundamental questions of human culture "Who am I?". Socrates taught: " Know thyself!", Petrarka asked "who are we, where are we from and where do we go?". The problem "what is a human being?" is one of the main open philosophical questions.

Relations between subjects having different degrees of complexity (an individual, a group, or a community) may be designed as a multilevel and multifaceted interrelation process, which acquires increasingly more diverse forms. However, at the centre of the mentioned interrelation, there will always be a personality playing an active part in the communication processes. Such a personality should be capable of broadening the variability of the connections, as well as be capable of searching for new ways and directions of interaction.

Such a dynamic situation can be developed in any cultural community, and may become a new model of interaction in the contemporary world. The emergence of the on-line personality, in turn, reflects the fundamental changes taking place in the society; these changes are symptoms of our society being transformed into a digital society.

On-line Identity or Personal Identity Online (PIO) [1, 8, 16] is a way of choosing how to present oneself as a personality in network. The concept of PIO personifies a specific characteristic of an individual's behaviour in a network environment, which manifests itself in the form of a unique opportunity to form and exhibit the individual's identity differently than it is done in reality.

Personality is something that belongs to a person, a model that develops in his/her head, his/her individual identity and collective consciousness; this model has evolved in certain places: society, family, and culture. In contemporary life, the distinction between online and offline is being blurred. The life of people as informational organisms is rapidly becoming normal life and greatly affects personality formation. The line between a real person (or the ''offline'' one) and his projection onto networked reality (the ''online'' self) is becoming blurred and the most intimate thing that we can have - our own persons and our own selves - are being affected significantly by these technologies.

Self-perception of an individual in a digital society not only may change - it is already changing, and not only cognitively but also through behaviour. An individual may formulate and often formulates his identity in a network differently than in the traditional world. Each person creates his own infosphere during his life by presenting knowledge about himself that he himself produced, by his thoughts and his memories. Many people are now constructing their alternate personas online; social networks, which are assumed to be the place where one reveals oneself to others, are also being used in such a way as to present entirely new personae to the public. Some people prefer using their real names while acting online, whereas others prefer to be anonymous, identifying themselves by means of pseudonyms that reveal varying degrees of personally identifiable information [12, 13].

Papert [15] noted that a personalization process is strongly connected with expressing and forming the personal identity. According to Papert, the meaning of "personal identity" comprises: a) subjectivity of knowledge regarding the meaning of actively using personal knowledge that exists in one's mind, instead of using exclusively the commonly accepted objective resources of knowledge; b) personal knowledge instead of using a pre-structured and commonly accepted subject knowledge.

Papert emphasizes the intimacy of the human presence in intellectual environments; he mentions that the personal component has always been not only an essential component of human environments, but also an exclusive one. At the same time, virtual micro-worlds, when representing a highly personal environment, are often devoid of the most important component: the social component.

According to the Papert's constructionist approach, the human environment of the new digital reality should combine its classical personal/intimate component with a social component. Recently, such a component was recognized as collaboration of inforgs within the new, networked reality (infosphere). The recognition by humans of themselves and of informational artefacts as inforgs, which inhabit the infosphere is one of the main factors of the digital society.

2.3 Enhanced social awareness - factor of the social culture

Technologically, the infrastructure of digital society is a network that has: a) the capability of receiving various types of content from its participants (inhabitants), and b) the capability of supporting intensive communication among a huge number of participants (including the exchange and the common analysis of various types of content), and as a result – the capability of forming virtual communities.

The dynamism of a modern human being expresses itself in formation and establishment of a Network Society. Socialization becomes the main component of communication in today's networks. The social character of the networks contradicts to hierarchical models of communication, where the principles of vertically arranged status and suppression dominate. The social network converts interaction between its users into stable social communication, and brings it to a higher level in developing a new digital society.

The network society is a direct challenge for a civil society, which was the main achievement in culture of the industrial era. Individual success in the era of a civil society was measured in terms of success related to the individual character of professional activities of a scientist, an engineer, or an artist. Today, the transition to so-called hyper-connectivity generally changes the above paradigm. Today, the network personality is, first of all, a personality that explores virtual space together with other network personalities and creates multiple virtual communities as basic structures of the new-born digital civilization. Such a new social situation we suggest to characterize as an *enhanced social awareness*. The awareness comprises two main factors: a) perception of Social Media as a new platform of forming the collective consciousness; and b) perception of digital artefacts as socially behaving entities.

Social media is traditionally defined as numerous Web applications supporting the creation and exchange of user-generated content. Today, when the social media plays a significant role in the social life we consider it as a cultural phenomenon, substantially intensifying and enhancing interpersonal communication and significantly altering the nature of the relationship between an individual and a society ("personality-society"). Note that the relationships "personality-personality" and "personality-society" are immediately perceived as simple and are unprecedentedly multifaceted. The simplicity of relationship/mutual connections is clearly seen in the availability of new communication tools (from mobile devices to social networking sites) for any level of society, regardless of education, age, and economic status. Diversity of communication connections is a new phenomenon related, for example, to the above-mentioned PIO, and to the fact that an identity and personality in cyberspace can be perceived not only as a real person, but also as an artificial object.

In the era of social media, social consciousness is formed in accordance with new, previously unknown principles, thus establishing new goals in all public institutions. In Web 2.0, the possible forms of network activity are extremely diverse. These forms include blogs and forums, social networks, wikis, etc.

The most important fact to be recognized in the culture of the new digital society is that a personality has increasingly more activities in the virtual world, and that a personality actually lives in the virtual world in parallel to the real world. The virtual world is not only the Internet in its common meaning. It is the infosphere, which is built by humans on the top of reality. This infosphere is integrated in the contemporary reality. Actually, the infosphere forms the new reality. However, it essentially differs from reality in its traditional sense. The enhanced social awareness is rooted in the fact that people realize aware about their personality not only in reality, but also in their individual infosphere, which communicates both with infospheres of other people and with informational artefacts.

The new, networked environment inhabited by inforgs, has not been studied yet. The infosphere is still at the stage of self-forming. In this new environment, people actually and in quite a strange manner return to their "pre-historical" past (e.g., to forests or to the Wild West) when everything was unclear and

unpredictable regarding people's interactions with nature. Today, the situation is analogous, but nature has been replaced by the network. The recent situation in infosphere is often called “a digital feudalism” and estimated the relative state of the digital society as the early medieval period. The important feature of the new environment being explored today is its unpredictability. In contrast to the unpredictability of nature, the unpredictability of infosphere is absolute, since people have never experienced it and do not have any ideas about what it is. On the other hand, in contrast to other emerging technologies (e.g. Nano-technologies, gene engineering) infosphere is relevant to everybody since it is our new reality, i.e. everybody lives or will live in it in the near future. It is obvious that a new, networked consciousness will be formed in such a new world.

2.4 Emergence of Cyber-physical Systems – factor of technological culture

Cyber-physical Systems (CPS) represent a specific branch of complex technical systems conferencing knowledge and technologies of computing, networking and informing, and those of physical artefacts and engineered systems towards operating and servicing in human and social contexts. In the cultural context, we consider CPS as the artefacts owing characteristics that allow them to be inhabitants of the newly recognized infosphere – a new habitat corresponding to the digital society [17].

Humans behave as informational beings not only in cyberspace, but also (and even more) in reality. However, the reality is permanently changing by accommodating more and more other informational entities, which, in turn, may also serve as artefacts. Awareness about such an unexpected phenomenon is an important feature of the digital epoch.

Traditionally, people perceive technology as a generalized tool assisting them to solve specific practical tasks. Such a concept supposes that computers, communication means, software means, gadgets are considered as various “technological tools”. Moreover, the mentioned opinion is supported by the belief that people do not interact with such “tools” in a social manner. Surprisingly, such a perception about technological means logically fails in the case of communication means and computer programs. Indeed, people socially interact with means of digital communication. It takes place even if people do not perceive the communication means, programs and media agents as partners in the frame of a common community. (It is interesting that all roles existing in the world of social interaction are applicable to the world of communication and to the world of computer programs).

That delusion stems from two reasons:

1 Evolution. The main portion of human beings' evolution passed without any technological communication means. Such means appeared only in 20th century. During the previous 200000 years of evolution, only those who acted socially could be considered as personalities. People are therefore accustomed to think like that. On the other hand, our brain has an ancient cliché that any active entity is a live organism, and that any functioning entity is either a human being, or something similar to a human being. This cliché is very powerful and controls our brain irrespective of our understanding.
2 It is a common preconception that a social object is perceived as an object with intelligence. Our society was not prepared to perception of, and to co-existence with machines, which behave socially.

The modern communication environment captures our consciousness, though it still supports our old schemes of behaviour and perception developed and proven by ages of evolution. People react to info-imitations of natural objects or social roles as if such imitations were real objects. Indeed: computers, artefacts, other informational organisms demonstrate social characteristics/behaviour and receive social reactions from people. A simple example of the social interaction with artefacts is our collaboration with mobile devices. The level of the personalization of a device strongly depends on involvement of its owner in various social and context aware activities. As a result, at a certain level of personalization, the complexity of interacting software agents, apps, or/and mash-ups leads to transforming the device into a very complicated informational organism. Interaction with such a device requires specific communication

skills both from its owner and from any other possible user. Another example is a children toy that, when being connected to the network, changes its behaviour due to updating its embedded software or interacting with another toy.

We are to live in the heterogenic society inhabited by inforgs. Such a society comprises both human beings and artefacts having some special features, while the artefacts undergo very rapid evolution and become more and more socially meaningful.

Thus, a very interesting and unprecedented cultural phenomenon of the digital society is the emergence of cyber-physical systems, the systems that humans create by themselves providing them with ability of social behaviour. Needless to say that such an objective is new in engineering practice. We call such a design as *socially aware design*.

The concept of socially aware design is different from the known concept of *socially aware computing*, which comprises: a) novel methods for monitoring and analysing social interactions; b) subsuming the information from many individual interactions; and c) developing collaborative, "social" algorithms [14]. In contrast, the proposed here socially aware design is *design for social behaviour* of the artefact to be designed. In other words, the aim of such design is to provide the socially recognized interaction of the artefact with other inhabitants of the network environment.

3 Characteristics of CPS as Symptoms of Digital society

In this section, we discuss symptoms of digital society [2] and their manifestation in a form of characteristics of cyber-physical systems.

3.1 Blurring the distinction between reality and virtuality

The dualism "reality-virtuality" has deep roots in human history. Actually, this dualism accompanied the mankind while creating culture [2].

The post-industrial, digital society is characterized by intensive virtualization. It is particularly evident in the fact that people interact with the environment indirectly, through computer interfaces. As a result, environment actually loses its real character and becomes virtual for the people. One simple example of such virtualization relates to behavioural patterns of the people being members/citizens of a digital society. Success in various activities of these people more and more depends on their ability to adequately and effectively react to events by means of a computer interface (rather than on their actions in reality). Moreover, the computer interface sometimes replaces reality even in trivial situations. For example, ten years ago people checked external temperature using an outdoor thermometer, but today people will most probably look for reports about the external temperature, using the Internet, or will activate software applications in their mobile devices.

However, the virtualization is not the only direction of the blurring. There is also a reverse trend (the trend of reification) – from virtuality to reality. It appears particularly in the fact that computer simulations acquire real significance, and become more and more indistinguishable from reality. In other words, we deal with the two-way process of blurring the distinction between reality and virtuality.

Historically, humans perceived virtual (non-real) entities or events first as magic, then (since Enlightenment) as something natural but unknown that can be and has to be realized/studied, and later (since the Industrial era) – as something technological, artificial, created by humans. The transformation was gradual, but the three steps of perception always existed. Different epochs can be characterized by different relations between reality and virtuality. For example, in the Middle Ages, being the era of religion

and art, the virtual component dominated, while in the Industrial era, the reification took place. Nevertheless, the dualism reality-virtuality always remained.

Today, in most cases people are regular to consider non-real phenomena as artificial. It is interesting to remind Max Weber's "Disenchantment of the World" [7] as the aim in human cognition and science research. In this sense, people today, in the digital age make something opposite: they enchant the world. Indeed, we already ceased to be surprised when find out even extremely unexpected and amazing technological innovations. In a sense, people began to believe in miracles! The Industrial society was the society of rationalism and reification. In contrast, the digital society is the society of de-reification, society, where virtualization of the reality dominates [12].

Since the Industrial epoch and wide distribution of Modern educational system, people are accustomed to consider real physical events and process as based on natural laws. The majority of nature laws have two important features. First of all, these laws deal with physical phenomena rooted in conversion of energy. Secondly, the majority of the laws are linear, which means they are described mathematically by linear equations. The whole traditional school science curriculum is based on the above limitations.

In contrast, non-real entities/events are usually associated with processes, which do not correspond and even contradict to the conventional laws of nature. Mostly, these new events and processes are: a) based on transformation of information but not only conversion of energy; b) described by using algorithms but not only linear equations. Before the digital era, such phenomena being unexplainable by traditional laws were classified as non-real.

Beginning from the 20th century, information technologies, created a new perception of unexplainable phenomena. They are not connected with nature directly any more, but more and more considered as technologically created. In other words, today, non-real becomes artificial, which means – real. Virtual and real entities/events are converging. A cyber-physical system – is a bright and important example of the converging. Indeed, comprising both physical (real) and digital (virtual) parts such system implements the hybrid system where real and virtual portions are inseparable.

3.2 Blurring the distinctions among people, nature, and artefacts

During the early mankind history, it was quite easy to distinguish artefacts from nature. Some blurring of the distinction started since the Industrial era, when people acknowledged that they are part of nature, in full continuity with animals. Since the industrial era, artefacts and nature have become intrinsically connected, through the establishment of industrial development. Later on, due to success of biotechnology and medicine, humans and artefacts have also become linked [10]. Recently, massive integration of various sensors into the human life, and the progress of cognitive sciences and biotechnology have blurred the distinction between humans and artefacts. Today, the intensive growth of such and other artefacts, along with implementing the idea of almost full monitoring - actually negate the concept of nature.

If distinctions between people, nature and artefacts no longer exist, what does it mean, for example, in the ethical domain? What is the impact of such a blurring on the human culture in general, and on art, literature, education in particular?

In the Digital society, both of the above-mentioned symptoms (i.e., both of the "blurrings") are reflected by the network personality. These symptoms affect one's self-recognition within the world; consequently, the changes in the self-recognition affect the spiritual internal world of a person and finally - the spiritual culture in general: art, literature, philosophy.

Obviously, it is impossible to predict exactly what will be the form and the contents of the spiritual culture

of Digital Society, since it is presently at its development stage. However, the characteristics pointed out above indicate one important trend, namely, the trend of forming a new personality, which is the network personality.

The blurring distinctions among nature and artefacts can be seen in Cyber-Physical Systems (CPS), which are hybrid systems that can be classified neither to pure nature nor to pure artefacts. Moreover, in CPS, the blurring between machines and humans can be seen. Indeed, being able to have a quite sophisticated social behaviour, such artificial systems (in communication therewith) clearly can be perceived as humans.

Another important manifestation of blurring the distinction between nature and artefacts is the emergence of analytical research methods in engineering. We are accustomed to analytical methods as dominating in the classical experimental science. To achieve the main goal of the science research, which is the Max Weber's "Disenchantment of the World" [7], researchers use complex analytical equipment. While science equipment is mainly analytical, than the instrumentation of engineering can be characterized as synthetic. The engineering equipment is usually intended for designing and fabricating new artefacts. Today, the situation has a tendency to change. The main sign of this change is the wide use of analytical instrumentation in engineering researches and practices (for example, various probe stations). Engineers analyse their own creations in order to study certain specific features and technological characteristics of the artefact. It looks that people after disenchanting of nature deal with "Disenchantment of the Artificial World"!

We consider the above new tendency as reflecting the symptom of blurring among nature and artefacts since scientists demonstrate similar attitudes when analysing behaviour of both natural and artificial objects.

3.3 Reversing from Scarcity to Abundance of information

The third symptom, namely, the abundance of data (information), drastically distinguishes the new digital society from its predecessors. There was always a shortage of information in previous societies. Access to information (like access to any valuable issue whether it is real or spiritual) was always both limited and time consuming.

Today the situation has radically changed. We live in the era where information is easily accessible and sometimes is even excessive. Under the new conditions, the place of information in the system of human values is being changed. One of the most important changes caused by the information boom is the change affecting scientific activities. In particular, scientific methodology undergoes some important changes.

Similarly to the cases of networked personality and network society, a specific symptom exists that is related to the abundance of data. More specifically, it indicates *reversal from scarcity of information to abundance of information*.

The social consciousness regarding knowledge is underscored by the omniscience utopia. The above is based on the idea that, if we knew everything that there is to know, we would act perfectly, or, alternatively, that mistakes are direct results of lack of knowledge [2].

Contemporary people, being the procreation of the encyclopaedic ideal, are now subjected to a new reality whose main constraint is not the knowledge, but instead - the peoples' attention capacity. Knowledge is becoming ubiquitous in space and in time, easy accessible and always available. Today, knowledge is like what used to be a natural resource: it is plentiful and limitless. Peoples' concept of boundlessness has switched from natural resources to knowledge.

Instead of aiming at some encyclopaedic overview to understand any idea, people force themselves to survive within the sea of information content represented in various forms. Moreover, the information sea

is not “clean” since it comprises a lot of data of questionable quality from untrusted sources, etc. People deal with the abundance of information, which in turn require new filtering activities like, for example, digital curation [4].

It is impossible to quench one's thirst by drinking water from a dripping faucet; similarly, it is impossible to do so from a fire hydrant. The transition from total scarcity to total abundance and even redundancy of information, as manifested by the abundance of data in a digital society, is fundamental and should be studied.

It is obvious that such an abundance of data has a very special meaning to our scientific culture as humans. Indeed, the shortage of information and the hard access to knowledge served as the basis of our science and the technology, which, in turn, formed the culture of industrial society. How does data influence science and technology? This will be discussed next in the context of culture.

“Since at least Newton’s laws of motion in the 17th century, scientists have recognized experimental and theoretical science as the basic two research paradigms for understanding nature. In recent decades, computer simulations have become an essential third paradigm. As simulations and experiments yield ever more data, a fourth paradigm is emerging, consisting of the techniques and technologies needed to perform Data-Intensive Science” [5].

Today, in the era of ubiquitous access to data, the process of acquiring new knowledge has been changing significantly. Intensive growth of data, being transferred to cyberspace, has given rise to a new science research paradigm, the so-called Fourth research paradigm, which is Data Intensive Science [5]. New ways to produce, store, and process data affect the manner of how scientists work, think, learn, and collaborate. The speed at which any given scientific discipline advances depends on how well its researchers collaborate with one another and with technologists in areas of e-Science such as databases, visualization, and cloud computing. Obviously, the new paradigm of science research affects academic education. It relates not only to the style of teaching or to new learning activities and environments, but also to something that is much more significant, to the fundamental values of academic education. Having been formed in the Enlightenment era, and having undergone intense development during the industrial epoch, traditional values of science are continuing to change. This emerging tendency should be studied in depth, since its influence on society, social consciousness in general, and on the educational system specifically, cannot be overestimated.

Summarizing, the “reversal from scarcity to abundance of information” affected the classical science methodology and gives birth to the Forth science paradigm called “Data Intensive Science”. Notice that it is the phenomenon of science culture. What about the technological culture?

In the sphere of technological culture, the situation is different. We consider the symptom of “reversing from scarcity to abundance” broader than in the context of information. We assume that the Industrial society, being the society of scarcity, have formed a specific approach in engineering, which is reflected in all stages of design. The main principles of design were formulated in the Industrial society, when the Technology, actually, was born as an independent scientific discipline. When we are talking about the design process, we usually deal with some constrains or criteria of optimization. Classical criteria of optimization were: overhead, price, size, power dissipations and the like. The process of optimization usually comprises a number of so-called trade-offs among the criteria. All such criteria are criteria that based on scarcity. In the situation of abundance of resources, the optimization criteria are going to be changed. Along with the traditional scarcity based criteria, new design principles are emerging. Indeed, who cares about overhead if resources are often almost unlimited?

New optimization criteria being based on the abundance of recourses are, for example: security, trust,

privacy, reliability, sustainability and others. Design methodologies created according to these new criteria assume solutions with significant overhead in order to achieve the main goals of the design.

The above criteria have an important specific character: all of them are intended to optimize the future functioning of the system but not just the system itself. Indeed, such design methods as: Design for Testability, Design for Security, Design for Sustainability etc. are more oriented on the future functioning of the system than with the system's itself.

The first signs of the above tendency could be mentioned a couple of decades ago, when designing of so-called self-checking digital circuits became the challenge. Designing self-checking circuits required a specific kind of thinking, which comprised predicting their future functioning. Designers had to develop a so-called fault model of the circuit, by constructing possible behaviours of the system if a specific fault occurs [9, 11]. Actually, the design of self-checking circuits is one of first examples of the new, future functioning-aware design. Today, the majority of designs have such a character.

3.4 Shifting from the primacy of entities to the primacy of interactions

One of important symptoms of the digital epoch is *Reversal from an entity's primacy over interactions to interactions' primacy over entities* [2].

This symptom can be explained as follows.

People pay more attention to what entities are, and consider interactions there-between as a secondary issue. They often consider the stronger leadership or the increased power or control as the main sources of problem solving. Centralized, hierarchical structures play a very important role in social consciousness, despite of so important intellectual achievements/concepts like democracy, human rights, open society, etc.

A new digital society inevitably requires to rebalance the relationship to the self (focus on identity) with the relationship to the other (focus on interactions). It can be done by using a relaxed approach for identity and a strengthened approach for otherness. With the digital transition, the importance of interfaces and interoperability is central. The significance of interactions becomes a matter of fact, and identity is viewed as the result of all interactions.

The network of objects and its structure are more significant than the elements/objects. The essence of an object has not changed. However, our perception of the object, which becomes interconnected with other objects, has changed. The object is not an inanimate entity anymore. Being interconnected with other elements of the network, the object has acquired some social content. In a traditional situation, an object being the main entity always had a dominating role in comparison with the network. Today, in a hyperconnected environment, the situation becomes inverse: an object cannot be the main issue any more; its behaviour cannot be predicted and designed in advance without knowing the structure and the content of the network. Obviously, in the interconnected situation, the network (the interactions) is primary, while the object (entity) is secondary.

Replacement of the humans' idea of the object's priority by the idea of giving priority to their interaction reflects (at least partially) rejection of the idea of a traditional society and manifests transition to a new, network society. Although we cannot characterize the new digital society precisely, it is obvious that the above characteristics allows better understanding the trend of the new society character.

Let us conclude the Section 4 by summarizing above discussion. Remind that, according to our approach, the specific characteristics of cyber-physical systems correspond to the main symptoms of digital society. We have divided the discussed CPS characteristics for two categories (ontological and epistemological) and summarized them briefly in Table 2.

Table 2 Ontological and Epistemological characteristics of cyber-physical systems.

	Ontology	**Epistemology**
Blurring distinction between reality and virtuality	1. Indistinguishability of reality and simulations	1. New perception of unexplainable phenomena
	2. Replacing reality by computer interface	2. Awareness about hybrid entities
Blurring distinctions among people, nature, and artefacts	1. Emergence of smart environments	1. Emergence of analytical research in engineering
	2. Social behaviour of artefacts	2. "Disenchantment of the Artificial World"
Reversing from Scarcity to Abundance of information	Emergence of ontology of information abundance	Data Intensive Science - the 4-th Science Research Paradigm
Shifting from primacy of entities to primacy of interactions	Ontology of interactions replaces ontology of things	1. Studying phenomena as interactions of entities
		2. Awareness about networked reality

In the table, rows correspond to symptoms of Digital Society, columns – correspond to ontological and epistemological characteristics of CPSs. For example, two ontological characteristic of CPS corresponding to the "Blurring distinction between reality and virtuality" are: 1. Indistinguishability of reality and simulations; 2. Replacing reality by computer interface, while the epistemological characteristic of CPS corresponding to "Reversing from Scarcity to Abundance of information" is "Data Intensive Science".

4 Conclusions

The focus of the paper is on symptoms of the coming digital epoch, and on realization of the symptoms in Cyber-Physical systems.

We have discussed the following four symptoms of the digital society:

- blurring the distinction between reality and virtuality;
- blurring the distinctions between man, machine, and nature;
- reversal from scarcity to abundance of information;
- shift from the primacy of entities over interactions - to the primacy of interactions over entities.

We show that all the above symptoms are intrinsic features of CPS, which put the concept of the CPS into the focus of discussions about the digital society.

We believe that he essence of the digital revolution can be formulated as peoples' awareness about existence of infosphere inhabited by inforgs, which are both humans and artefacts. We state in the paper, that the inforgs are none other than cyber-physical systems able to communicate with other inforgs. As a result, their behaviour becomes social in a certain sense.

We have analyse d the above symptoms and have shown that each of them represents a specific cultural trend of the increasingly developing digital society. Such trends, which represent on-line personality, enhanced social awareness, and emerging of cyber-physical systems, in turn correspond to the three faces of culture: spiritual, social, and technological. By mapping major characteristics of the digital society into the space of culture, we reveal the main cultural directions of the coming Digital era.

The main contributions of the paper can be summarized in the following three ideas that were formulated and discussed:

1 Artificial informational organisms (inforgs) are none other than cyber-physical systems (CPS).
2 Emergence of CPS is the major factor of technological culture of the Digital epoch.
3 Design of CPS becomes the socially aware design, which is a synthesis of inforgs, being co-inhabitants of humans in the digital society.

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International Journal of *Design Sciences and Technology*
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Towards a better, stronger and sustainable built environment

Aims and scope

Today's design strongly seeks ways to change itself into a more competitive and innovative discipline taking advantage of the emerging advanced technologies as well as evolution of design research disciplines with their profound effects on emerging design theories, methods and techniques. A number of reform programmes have been initiated by national governments, research institutes, universities and design practices. Although the objectives of different reform programmes show many more differences than commonalities, they all agree that the adoption of advanced information, communication and knowledge technologies is a key enabler for achieving the long-term objectives of these programmes and thus providing the basis for a better, stronger and sustainable future for all design disciplines. The term sustainability - in its environmental usage - refers to the conservation of the natural environment and resources for future generations. The application of sustainability refers to approaches such as Green Design, Sustainable Architecture etc. The concept of sustainability in design has evolved over many years. In the early years, the focus was mainly on how to deal with the issue of increasingly scarce resources and on how to reduce the design impact on the natural environment. It is now recognized that "sustainable" or "green" approaches should take into account the so-called triple bottom line of economic viability, social responsibility and environmental impact. In other words: the sustainable solutions need to be socially equitable, economically viable and environmentally sound.

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