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PAPER

Philosophical Background of Computational Thinking

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ABSTRACT

The presented study deals with the philosophical background of computational thinking, which is currently widespread in educational programs across all types of education. The current era is characterized by a turn to the digital environment, which is organized especially by algorithms and the collection of big data. New technologies have literally become the backdrops of our everyday life. The problem, however, is that society uses new technologies as black boxes, which also leads to the fact that it is difficult to adequately interpret and change this technological totality (technological or digital sublime). Computational thinking thus offers a cognitive tool for navigating this technological turn. It also seems that computational thinking can serve as a flexible thinking tool in the context of Society 4.0.

KEYWORDS

computational thinking, new technologies, Society 4.0, automation and robotization

1 INTRODUCTION

According to experts, we find ourselves in a time that is referred to as the fourth industrial revolution. This concept was originally defined in the context of industry and production, but new technologies are also being used in other social areas. New technologies have thus completely grown into the sphere of public and private life [15]. Technologies have thus become the backdrop to our everyday lives, and we can no longer imagine life without them [9].

Thus, in the jargon of postmodern philosophy, we can talk about the transformation of life itself (onlife) and therefore the transformation of the social subject itself [11]. To a large extent, the subject's decision-making is determined by the syntax of algorithms and big data, which are conveyed to us especially by the applications of new technologies: these are the medium of new services and business models. Algorithms – without our being fully aware of it – offer us certain instructions on how to navigate in a world constituted by data: algorithms determine our databases of films or music from which we can choose; they tell us which way to go; where we should check in; by what means to travel there; or even whom we should meet there. We can therefore speak of a certain version of technological determinism [21].

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In this way, social reality is deprived of chance and gives the impression that it is possible to transform it into a formal language of ones and zeros (the main interface of new technologies). Such an assumption can be found, for example, in the theory of dataism, which assumes that one day it will be possible to describe the entire universe in a formal language (Harari). We already know that the interface of ones and zeros can connect different technologies [9]. Every day we use the outputs of new technologies, but we have no idea how they work and what algorithms are hidden in programs, applications, services, and advertisements. Without realizing the implications, we use these technologies as black boxes, as functions into which we put data and then receive it [20].

Another problematic aspect is succumbing to the automatisms of thought associated with the fundamental functionalities of the human mind and consciousness, the so-called cognitive biases. These are amplified in the digital sphere, especially when harnessed to the exponential growth in computational power of statistical algorithms trained on cheap, suitably structured and accessible big data sets. This can be observed in recent decades with the phenomenon we have come to call by the confusing term *artificial intelligence*. Humans lack not only the biological makeup or historical experience to defend against the systemic and accidental abuse of these thinking tendencies (cognitive biases) in virtual and natural space, but also the moral and ethical frameworks [22].

We could therefore claim that the emancipatory program of the Enlightenment is incomplete because within Society 4.0 we unconsciously leave most of the decisions to the aforementioned algorithms. The algorithms do not even have to exert themselves; social reality is simplified to the level of formal language. This is why algorithms can be so influential. So let us not look for complexity in algorithms, but rather for simplicity in social reality. Our social reality is complex and diverse, but due to algorithms, it is no longer random [15].

The colonization of social reality technologies has another side of the coin that raises considerable debates. These debates regard the very future of work and the organization of the social order in the age of automation, robotization and big data. The issue consists of the tendency to exclude people from the production process and to replace routine work with technology. Technologies are interconnecting with the economy and trying to find new ways of cheaper production where they save on expensive manpower [23].

New technologies are even changing our behaviour. Just ten years ago, we made different decisions in certain situations. The smartphone alone has transformed our behaviour and culture of habits into a completely new form. Smartphones have replaced walkmans, portable radios, all other portable media, conventional watches or calendars and diaries. In some cities, smartphones have replaced paper tickets for public transport or concerts, keys or other means providing entry and exit. We can also think about the culture of printed books, maps and guides, or everything we used for navigation. Even money as such is no longer needed. It was all turned into ones and zeros. After ten years, only the phone and chewing gum are left in our pockets. Even a camera is no longer needed to capture the Benjaminian moment here and now. Our life is designed by the smartphone [9].

We have therefore reached the point where it is necessary to think about a new pedagogical dimension that will help us navigate such a technological turn. Originally, teaching was aimed at mastering these new technologies, but today there is a need to understand new technologies in their essence – to understand how technologies parcel out our universe and how they work with individual facts/data. This gives us some insight into – in Fredric Jameson's words – the technological sublime.

However, it is necessary to study this issue in an interdisciplinary manner, on the border between the didactics of computational thinking and the philosophy of new technologies. One of the discussed tools that would help us to interpret the technological totality in this technological turn is the so-called computational thinking, which is quite flexible to the current dataism. The question remains, however, to what extent can computational thinking prevent technological determinism or even help create the social constructivism of technology [13], [5]?

2 PHILOSOPHY OF TECHNOLOGY AS A PRECURSOR TO COMPUTATIONAL THINKING

We tend to associate technology with something practical, something that reacts to specific problems: technology is therefore frequently considered a mere means to social goals. The fixed idea of this practice flows through history from the days of the Industrial Revolution (the first industrial revolution), which led to great social, cultural and political changes – literally transforming the world into what we know today: a world separated completely from nature [3]. The highlight of this period is undoubtedly the instrumentalization of technology, which completed secularization. A negative view of technology, and thus of the theory or even the philosophy of technology, can deprive the social science paradigm of a certain way of knowing and interpreting the contemporary world, in which technology is irreducibly connected to society itself. It is, therefore, necessary to look for a new philosophy of technology that will respond to the connection between technology and society – the 4.0 concept can be used.

This realization places theorists in the two basic camps of technological determinism and social constructivism of technology. On the one hand, technology is seen as a defining element of society when it has a major impact on society. On the other hand, technology is understood as a neutral element that serves only selected social goals.

The first approach, the so-called instrumental technology, connects with the value system of society (cultural and political context). In this context, technology is understood as a neutral means to social ends. Technology is only a means to achieve efficiency. This approach, which can be considered purely functional, believes that technology is designed outside of political ideologies. The second approach, the so-called substantive one, assigns a certain autonomy to technologies that deviate from traditional and competitive values. In this context, technology is not considered a neutral means, but the negative consequences of technology for humanity and nature are emphasized here. Technology has become part of everyday life, and it is impossible to separate it from society. Technology determines and shapes society; it governs society. In extreme cases, we may encounter ontological models built on the claim that we live entirely under the sway of an autonomous technological (sign or system) matrix [2].

We could discuss technological determinism and social constructivism of technology. The first direction refers to a prescriptive description of reality, while the second direction points to a dialectical relationship between society and technology. However, social constructivism works with the so-called democratization of technology, i.e., with how people/society can intervene in technology through law, politics, initiatives, and norms. In this study, we rather deal with the more technical dimension of how to intervene in technology – through the so-called computational thinking, which is understood here as an active didactic element that can also design technology from the inside. For this reason, we will rather focus on technological determinism.

3 TECHNOLOGICAL DETERMINISM

Technological determinism argues that technology determines the overall structure of society and culture. However, the polemical question remains whether technologies are completely independent of humans. Although the main pioneer of this term was Marshall McLuhan, for the socio-political concept it is necessary to return to the initial theorization of this phenomenon in the work of Karl Marx, who pointed out the direct influence of technology on social relations in which technology is part of the so-called base (*base-superstructure* model). Even current theories see technology as the main driver of industrial revolutions. The problem with this model is that it works with simple/mechanical causality, where one phenomenon is explained by another phenomenon. In this way, historical materialism degraded into vulgar Marxism (*Second International, Stalinism*). In the context of 4.0, we can also encounter a certain variation of technological determinism within normative initiatives that work with the assumption that the implementation of Industry 4.0 will lead to the transformation of the entire society (industry, education, agriculture, healthcare, culture). Such a concept predicts the social areas that will be most affected by the implementation of 4.0 (smart factories, industry, agriculture, education, healthcare, or the entire structure of the labour market). Thus, a societal change is assumed. This delineation is problematic in the sense that it uncritically reckons with changes that have not yet occurred and at the same time requires new policymaking. For example, we will set up the education system and policy to produce a flexible workforce (regardless of whether the visions of 4.0 initiatives come true). However, a situation may arise when such workers will ultimately not be needed, and the labour market will once again face a shortage of specialists. The positive aspect of this view is that it works with the negative consequences that these changes can produce. The main problem discussed is whether the coming changes in the labour market (simple operations performed by people will be automated) will not be faster than the readiness of the social policy and employment policy of the nation-states. If there were to be a rapid deconversion, politics can get into such serious problems that it is legitimate to fear a threat to democracy itself. We know from history that excessive poverty and unemployment have always tended to modify democratic political regimes. However, tools are discussed here that should complement social policy and employment policy and prevent these serious problems. The Czech Republic's action plan and initiative refer to the following basic tools: moving the minimum wage limit, basic unconditional income, reduction of working hours, retraining, positive forms of job recharacterization (such as part-time jobs or home-office), definition of new conditions for self-employment. The Japanese initiative Society 5.0 even speaks about such a transformation of society, when a person will interact directly with algorithms and artificial intelligence: a symbiosis of technology and humans will be formed (the Internet of Things becoming part of the whole society). It is a concept of a cyber-physical system that will be applied not only within production but within society. We can talk about a new kind of post-humanism, where, alongside humans, a sum of autonomous artificial agents will participate in society, which will cooperate with humans. This is an application of artificial intelligence within the Internet of Things of the entire society, in which such a large amount of data will need to be sorted through an algorithm. This should imply a sophisticated system of services with autonomous agents and an overall move of society towards better cooperation and equality (*super smart society 5.0*). Although the application of artificial intelligence will be wide, we cannot talk about the problem of singularity or superintelligence. Rather, the problem will be that a person will be defined in relation to technological innovations, which will determine their situation in the totality of society 5.0. However, the problem with these deterministic approaches is still that they tend to plan and construct social configuration, which – as we know from history – has not worked well [8], [6], [1], [14].

The development of information and communication technologies combined with the predictions of the fourth industrial revolution, therefore, puts us in front of the question of how the nature of work (automation and robotization) will change in such a context. The unknown future of the development of the implementation of new technologies points us to two main scenarios that take place in the spirit of the aforementioned technological determinism. Technological determinism assumes that the development of society is uncontrollably linked to the development of technology (in this one direction). This means that – contrary to the social constructivism of technology – technologies have a direct impact on society and society is shaped by these technologies. If we stick to technological determinism, this means that we have two scenarios to work with: technological optimism (techno-optimism) and technological pessimism (techno-pessimism).

Technological optimism speaks of the fact that technologies have a direct impact on the operation of society, but as a result, society derives great benefits from this connection. If we talk about information and communication technologies, we can observe how these technologies facilitate our daily functioning and practice. For example, the development of the smartphone brought us many benefits. Over the last decade, the smartphone has changed to the extent that we can use it to perform almost all everyday operations (paying, listening to music, reading news, taking pictures, unlocking, navigating, communicating, etc.). If we relate it to the context of the fourth industrial revolution, it means that although there will be a certain loss of jobs due to the introduction of automation and robotization (the emergence of smart factories), new technologies bring new services and business models that will produce new jobs. As a result, there will be more new jobs than lost jobs. However, even technological optimism is not inactive and realizes that it will be necessary to intervene in the concept of education in a certain way so that the new working class is flexible and ready for these technological changes.

Technological pessimism, on the other hand, talks about the negative impact of technology on society. People are predetermined by technologies and to a certain extent, the technologies design their daily practice. If we relate it to the context of information and communication technologies, a person is completely absorbed by these technologies. It is no longer possible to do without these technologies. If we want to go on vacation, algorithms will choose accommodation for us; if we want to watch a movie, algorithms personalize the movie offer for us (the same goes for music streaming services); even when we want to meet someone, algorithms will choose a possible partner for us – if we actively work with new technologies, chance is pushed out of our lives. If we relate this to the context of the fourth industrial revolution, it means that technology will gradually transform the whole society (just as it happened in previous technical revolutions). The main negative here is the prospect of robotization and automation, which is expected to happen faster than nation states and their policies (employment policy and social policy) are ready for it. Which, as a result, could weaken the stability of society. If we did not discuss here possible alternatives of redistribution policy (such as paying taxes on machines or basic unconditional income, etc.), it is obvious that technological pessimism will also see possible emancipation from determinism precisely in education and flexibility. If we stop using technologies only as black boxes and know how they function/work inside, we can actively change them for the benefit of an individual or the whole society.

However, a necessary condition is to make the algorithms transparent, which would likely limit their effectiveness, utility, speed and evolution. To this date, there is no consensus in the scientific community on whether complex machine learning algorithms such as neural networks can be made completely transparent; in other words, to know how the AI makes decisions at each step, what the algorithm relies on, with the ability to change the body of the algorithm to match the intentions of the designers. In this way, we would then achieve reverse or dialectical causality – we would influence technology.

Based on both sub-directions of technological determinism, the perspective of computational thinking opens up here. The philosophy of computational thinking is precisely aimed at the issue of the so-called black boxes. People use technology based only on input and output; they do not know what is happening inside the technology. Computational thinking, unlike informatics, is no longer focused on control, but on understanding the processes that take place inside.

4 WHAT IS COMPUTATIONAL THINKING?

Computational thinking (CT) is currently one of the main tools for navigating the world of technological changes, applications and big data. Primary and secondary schools across all modern states are aware of this. CT offers students the flexibility and understanding of the natural world as a sum of logical operations that can be recorded using software. It is a sum of attitudes and skills that can identify and solve complex problems. Such a graduate possesses flexible thinking, and therefore better application in the labour market, which is gradually leading to automation and robotization, i.e., to Industry 4.0. In the hands of graduates, technology is no longer a mere black box that they only use, but they are able to actively interpret, use and change it [7].

CT recognizes the computational aspects of the natural and technological world around us. CT allows changes to be made in a rapidly developing world, bringing significant innovations to both individuals and society as a whole. It is a set of approaches to solving problems in such a way that a computer solves individual tasks. Within the framework of technological innovation, this is a basic skill that every individual should possess in order to meet the increasing demands of the fourth industrial revolution. These skills include a set of mental abilities that transform difficult and complex real-world problems into the type that can be solved even by a mindless machine without additional human assistance [18].

To successfully design algorithms (or programs) capable of calculations and to understand natural information processes, however, a special ability of thinking is needed. CT thus includes ways of thinking and exercises, which can be achieved especially through practice and in a team. It is therefore a rich set of interdisciplinary skills and can be used in a wide range of subjects in both natural and social sciences.

However, it is not the way computers think – even if we program them in this way; it is a set of different human problem-solving skills that are the result of studying the nature of computation. CT draws on skills such as creativity, interpretation or abstraction. At the same time, it is the ability to think mathematically, logically or algorithmically, focusing on every detail, as well as inventing new ways to further improve things. CT connects all these ways and thus constitutes a reliable algorithm design tool.

We can look at selected definitions of CT that appear in the professional literature.

Computational thinking: A way of solving problems, designing systems, and understanding human behaviour that draws on concepts fundamental to computer science [19].

Distilled down to its most fundamental elements, CT is comprised of four pillars:

- Decomposition
- Pattern matching
- Abstraction, and
- Algorithms (sometimes referred to as automation)

With these four skills, one can prepare any problem for a mechanical solution [12]. Computational thinking is the mental skills and practices for

- Designing computations that get computers to do a job for us, and
- Explaining and understanding the world as a complex of information processes

The design aspect reflects the engineering tradition of computing in which people build methods and machines to help other people [24].

It is not the way computers "think," though increasingly we are programming them to use computational thinking too. It is a collection of diverse human skills to do with problem-solving that result from studying the nature of computation. It draws on some obviously important skills that most subjects help develop, such as creativity, the ability to explain things clearly and teamwork. It pulls in ways of thinking from other subjects: thinking mathematically and scientifically, for example. At its core, though, are some very specific problem-solving skills, such as the ability to think logically and algorithmically, with a focus on every last detail, as well as being able to devise efficient ways to do things. It is also about understanding people [4].

5 COMPUTATIONAL THINKING IN BASIC EDUCATION (CZECH REPUBLIC CONTEXT)

The current Framework Educational Programme for Basic Education (FEP BE) [16, 17] is governed by new rules that respond to the rapid transformation of the market and the rapid development of new technologies. While the previous FEP BE (2005) was focused on the manipulation and control of computer technology, the current FEP BE focuses on the interpretation and understanding of technologies with the aim of solving specific problems. Emphasis is placed on computational thinking and its application. The first level of education is focused on practical work with data, while the second level of basic education is focused on the application of informatics concepts and the principles of the functioning of digital technologies. Pupils learn to formally write down and systematically assess procedures suitable for automation and to process even large and disparate files. In this way, computational thinking corresponds to the requirements placed on the flexibility of thinking of graduates and the requirements of Industry 4.0, which is largely based on automation and robotization.

6 CONCLUSION

It turns out that the emphasis on the importance of information thinking for the whole global digital polis has been more or less underestimated so far. With the massive and absurdly rapid adoption of advanced artificial intelligence tools such as ChatGPT, DALLE, Bard or the improved Bing, it has proven impossible to predict when and with what force these tools will spread massively to all levels of society. These generative chatbots are only a fraction of how artificial (imitation) intelligence has permeated the fabric of our existence – through and through. Humanity cannot be prepared – it shows that even university-educated people are failing and succumbing to the illusion of the omnipotence of these tools. It is impossible to prepare adequate legislative and ethical frameworks in advance when we do not know how fast this phenomenon will spread or what form it will take. Therefore, computational thinking as an approach will be a necessary element in the convoluted package of solutions to mitigate the unintended (or even destructive) consequences of the adaptation of these prostheses of the human mind. Informatics thinking shows that the emperor is naked, that artificial intelligence is just a tool of advanced automatic statistics that needs to be guarded and not trusted blindly. In this way, society can extract a lot of value from these technologies (which illusorily appear to us to be intelligent) that have become part of our everyday experience practically overnight. The key, however, is not to lose sight of their instrumentality and conditionality – let us not, as humanity, fall into the illusion that they are just tools, nothing more, nothing less. Seeing this illusoriness is what allows us computational thinking. It forces us to think like machines, to focus on the informational nature of the world, and thus to remove the veil of mystery from artificial intelligence and put it in its proper place – as tools for automating operations with information. Nothing more, nothing less.

It should be pointed out, however, that computational thinking does not replace critical thinking in a philosophical context. Computational thinking gives us a tool to solve technological challenges, but it does not give us a tool to interpret technology in a social context. What are the ethical and political implications of their use? In this context, it would be good to place computational thinking in the context of a critical theory of technology, which can interpret encoded social biases in technologies and, at the same time, distinguish whether it is a mere technology or a means of production. Hence, a critical theory of technology is driven by the philosophical vision of normative conceptions of democracy, and a Good Life and Society, judging technology according to ethical, social, and political norms, and seeing the construction and reconstruction of technology as fundamental to the human society and everyday life. A critical theory of technology thus creates a historically specific and normative critique of technology. It not only attacks life-negating and oppressive aspects of technology, but valorises empowering, democratizing, and positive forms and uses. Crucially, it attempts to discover and invent ways that technology can serve the interests of human emancipation and well-being, while aspiring to delineate emancipatory functions and uses for technology [10]. We could rather talk about the need for digital literacy.[1]

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[1]**Digital intelligence:** A comprehensive set of technical, cognitive, meta-cognitive, and socio-emotional competencies grounded in universal moral values that enable individuals to face the challenges of digital life and adapt to its demands. Thus, individuals equipped with digital intelligence become wise, competent, and future-ready digital citizens who successfully use, control, and create technology to enhance humanity.

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