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WAVES OF INFORMATION REVOLUTION[3]

Abstract

The article discusses the wave-like nature of information revolution: the wave of television the wave of television the revolution, the first three waves of personal computers, mobile telephony and the Internet, and the upcoming three waves of widespread social use of robots, knowledge engineering (inaccurately called artificial intelligence and Internet of things), and biomedical engineering. The basic thesis of this article is that the changes carried by the upcoming three waves will be even larger and deeper than the changes carried by in the previous waves that we have experienced in the last thirty years. For example, the approximate forecast of the number of robots in the world suggests that this number in 2050 will exceed the number of the world's population.

Keywords: development forecasts; new techniques of information revolution and its social consequences

1. Introduction

Although the literature on the causes and the social effects of the socio--techno-economic processes of revolutionary importance, today called *information revolution,* is huge see. eg. (Brynjolfsson and McAfee, 2014 Levy and Murnane, 2012) but in general it does not pay attention to the fact that these processes consists of successive waves, some of which are only awaiting us. Analysis of such waves is the subject of this article.

The first of these waves, or rather zero, because it actually preceded and prepared the information revolution was a wave of social penetration of television. It is the best documented and based on its character, we can draw conclusions about the nature of next waves.

The information revolution actually began with the first wave of social penetration of personal computers, after which quickly followed next two waves: the second wave of social penetration of mobile telephony and the third wave of social internet penetration. In the following paragraphs we will discuss the inventions preceding these waves, the actual delay from the invention to the beginning

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social penetration, and finally, the dynamics of these waves similar to each other, from which follows the possibility of predicting further course of such vawes.

The next waves are based on initial inventions made long ago, but the actual social penetration is delayed and we only expect an actual penetration of the fourth wave of mobile robots, of the fifth wave of knowledge engineering (commonly but inaccurately called artificial intelligence, Internet of things, etc.), And finally a wave of biomedical engineering . The actual social penetration of these waves, when the time comes, will probably have social effects comparable to or even greater than the social impact of the current three waves.

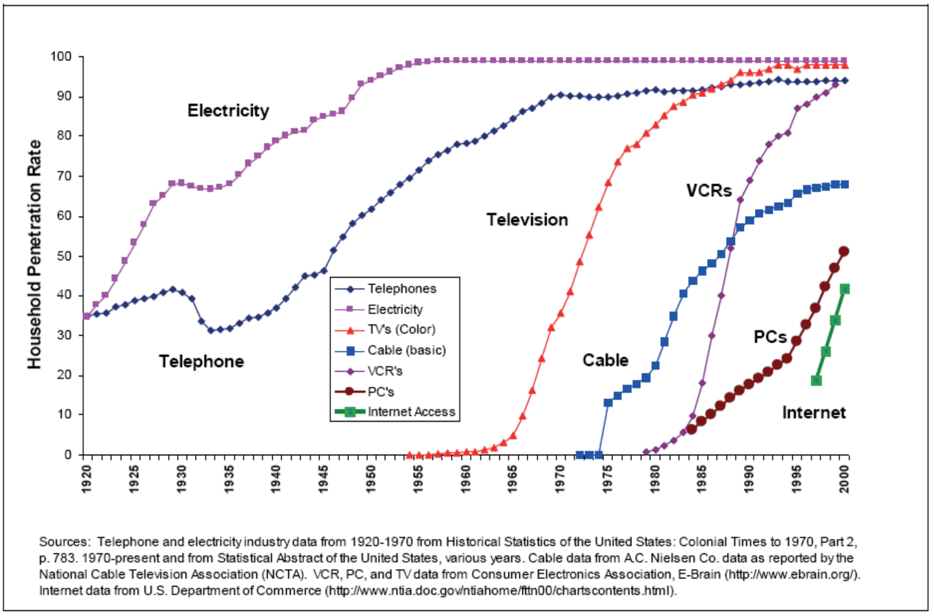
This is due to the fact that there is a specific relationship of positive feedback between the market and the high technology: the more the entrepreneur will gain through the use of high technology, the more he will be willing to invest in the further development and use of this or similar techniques. However, the processes of positive feedbacks lead to an avalanche-like development, constantly accelerating (until it hits the limit), which just today we observe. Therefore, changes of the way of life over the next thirty years will probably be even larger than those observed during the last thirty years. Thus it is especially important to analyze and provide a good understanding of the incoming waves. But to understand them we first need to analyze the waves which we have already experienced.

2. Characteristics of the wave of television

The first inventions, preparing TV (see. Wierzbicki 2011), date back to the year 1878 (Julian Ochorowicz in Poland, postulating the use of photocells for imaging) and 1880 (George Carey in the United States, similar concepts). Quite a long time, however, lasted until 1923 Vladimir Zworykin in the US developed a prototype electronic TV camera called Iconoscope, and in 1928 Kalman Tihanyi, also in the USA, has developed a prototype TV receiver. Since that time, again took a few years before in 1936, the BBC in London made the first televised broadcast media. While the beginning of the social penetration of television, namely the purchase of TV sets by a significant percentage of the population begins even in the US approx. 1950 and approx. 1960 in the case of color television.

The dynamics of the social process spread of color television in the United States compared to other, similar processes is illustrated in Fig. 1. While the previous processes of the social spread of electrification and telephone wire were slow and disrupted by crises and wars, the process of the social spread of color television was relatively fast and regular: a single percentage of the population to approx. 1965, then increase with the maximum speed of approx. 8% per annum, then gradual saturation, until in approx. 1995 the penetration of color television in the United States exceeded 95% of the population.

Fig. 1. The development of high-tech services and devices in the USA in the years 1920-2000.[3]



Social penetration of other products of high technology such as cable television, video recorder, the Internet had a similar, often initially slow, then greatly accelerated character. Characteristic for all of these processes is of large time delay from the original invention to the beginning of a massive social dissemination. For television the time (depending on the calculation method) reached possibly 80 years and at least 35 years. For other groundbreaking inventions such a time was slightly shorter, but also of about 40 years of age (as it will be illustrated by the analysis of next waves of information revolution). Various factors can cause that the delay time is shorter or longer. However, when public dissemination starts, the dynamic nature of these processes is mutually similar.

Therefore, for all these processes we can use similar mathematical models for statistical analysis and approximate prediction of their future development, see. (Grzegorek 2012), provided of course that we have statistical data about their current development.

Processes of social penetration can be predicted with the following mathematical models:

A logistic model is:

$$q(t) = a/(1 + b\ exp(-ct)); \quad (1)$$

[4] According to http://www.ntia.doc.gov/ntiahome/fttn00/chartscontents.html.

Gompertz model is:

$q(t) = a\ exp(-b\ exp(-ct));$ (2)

Double-inertial model is:

$q(t) = a\ (1 - exp(-(t-T_0)/T_1)\ T_1/(T_1 - T_2) + exp(-(t-T_0)/T_2)\ T_2/(T_1 - T_2))\ 1(t-T_0)$ (3)

where $q(t)$ is the estimated penetration of a technique in parts of the total population, and a, b, c, T_0, T_1, T_2 are parameters of these models which are determined by a statistical analysis of the previous course of penetration. The parameter T_0 indicates an observed start of penetration in the social model double-inertial; this model has the advantage over the other two which imply that the social penetration process starts at minus infinity. The parameter a denotes the saturation level of the penetration process measured in the parts of a whole, hence it can be theoretically set equal to one; but actual processes of penetration may omit part of the total population (children, etc.), or even exceed unity (if some of the users have, e.g. several mobile phones).

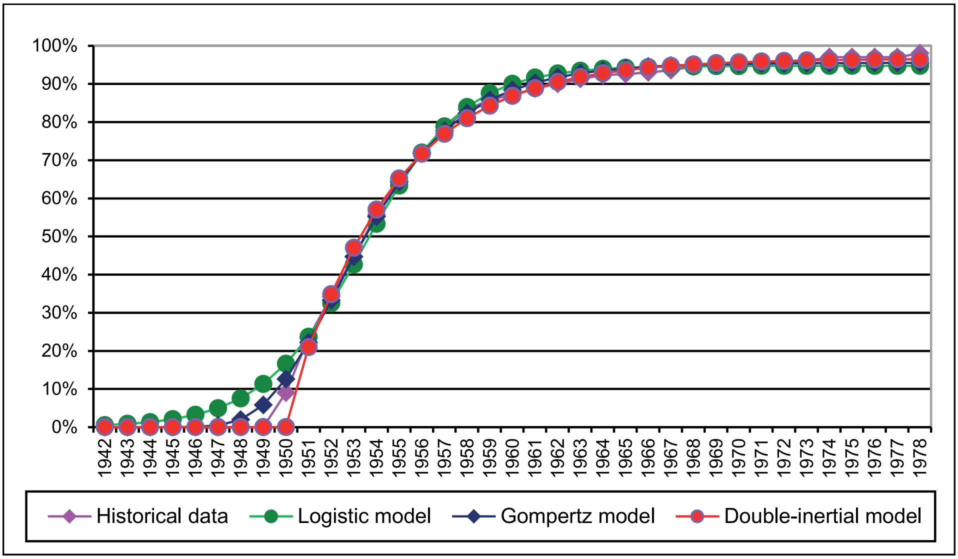
An example of the use of these models to the process of social penetration of color television in the United States is shown in Fig. 2.

The difference between these models is greatest in the initial phase of penetration and also for the largest projected increase rate. Statistical parameters matching these models were as follows:

For the logistic model: a = 0.9474, b = 7.377, c = 0.4498, which implies a maximum speed of rise $v_{maxl} = ac/4$ = 10.66%/year.

For the Gompertz model a = 0.9555, b = 2.805, c = 0.3261, which implies a maximum speed of rise $v_{maxG} = ac/e$ = 11.5%/year

Fig. 2. Dissemination of color television in the United States, approximating curves



For the double-inertial model a = 0.9663, T_1 = 4.2743, T_2 = 1.0570, T_0 = 1950, which means that the maximum rate of change is v_{maxd} = 16.2%/year, while the equation for its determination is rather complex:

$$vmaxd = \frac{a}{T_1 - T_2}\left[\exp\left(-\frac{T_2}{T_1 - T_2}\ln\left(\frac{T_1}{T_2}\right)\right) - \exp\left(-\frac{T_1}{T_1 - T_2}\ln\left(\frac{T_1}{T_2}\right)\right)\right] \quad (4)$$

The actually observed maximum speed of social penetration of television was (see Fig.1) about 15%/year, therefore the double-inertial model approximates best this speed, although it slightly overestimates the maximum social penetration (a).

While the social significance of television is obviously huge, it is not always positive; this was noted by Marshall McLuhan (1964) with his formulation that *media are massage* and Guy Debord (1967) with his concept of *spectacle society*. Today, the importance of television still increases because of its integration with mobile telephony and the Internet, which is discussed below.

3. Characteristics of the waves of personal computers, mobile telephony, Internet

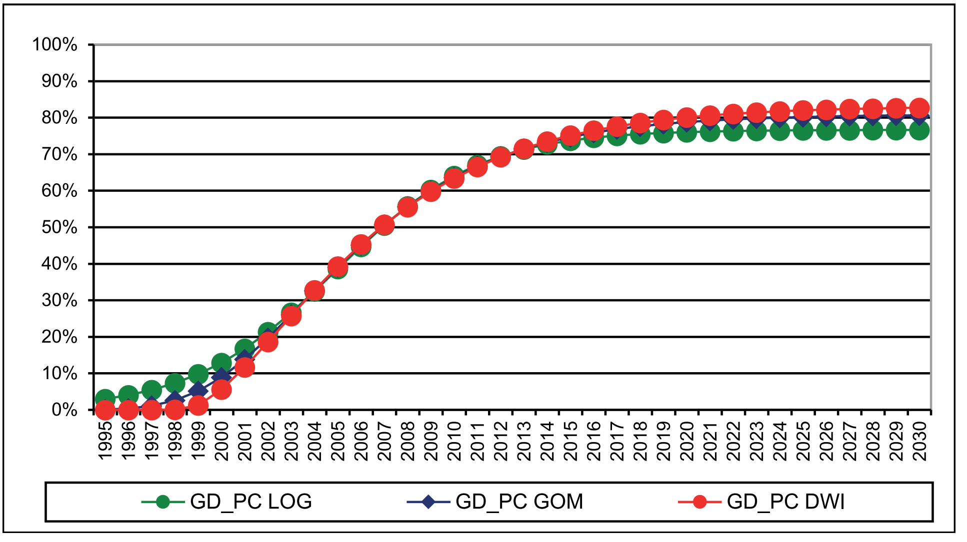
These waves began (in the sense of the beginnings of their social dissemination) quite a long time ago, today we observe only their progressive dissemination and integration of these waves, but with them also their growing social impact.

The wave of personal computers began not from the date of the inventions of electromechanical or electronic computers; these dates are 1931 (Vannevar Bush, analog computers based on telecom amplifiers with appropriate feedback loops) and 1936 (Konrad Zuse, digital computers initially based on the electromechanical elements of the telephone central relays, then gradually electronic vacuum tubes, and finally, transistors and integrated circuits). Due to the long-term improvement, a massive social penetration of computers began only in 1977, so with a delay of over 40 years, with the Apple II personal computer (Stephen Jobs and Stephen Wozniak). In approximately thirty years later, in 2008, the number of personal computers in the world has exceeded one billion (therefore more or less every eighth citizen of the world, including children and the elderly, used the computer) and grew further at a rate of about 150 million per year. Of course, the social penetration of computers in different countries differs greatly. E. g. if we apply similar models like to the wave of television, we obtain results for the social penetration of personal computers in Poland as shown in Fig. 3.

This figure shows that we can not expect 100% saturation of personal computers in Poland (whether due to the age of the users or their education), but predicted saturation levels are high (approx. 70-80%), although different for different models. Besides, this process can quickly change its character due to the expected progressive integration of personal computers with mobile telephony.

Inventions preceding the wave of mobile telephony can be interpreted diversely, because it was thought of and discussed since the beginnings of radio

Fig. 3. Social penetration of personal computers in Poland, approximating and forecasting curves (data until 2013, LOG denotes logistic model, GOM - Gompertz model, DWI - double inertial model)

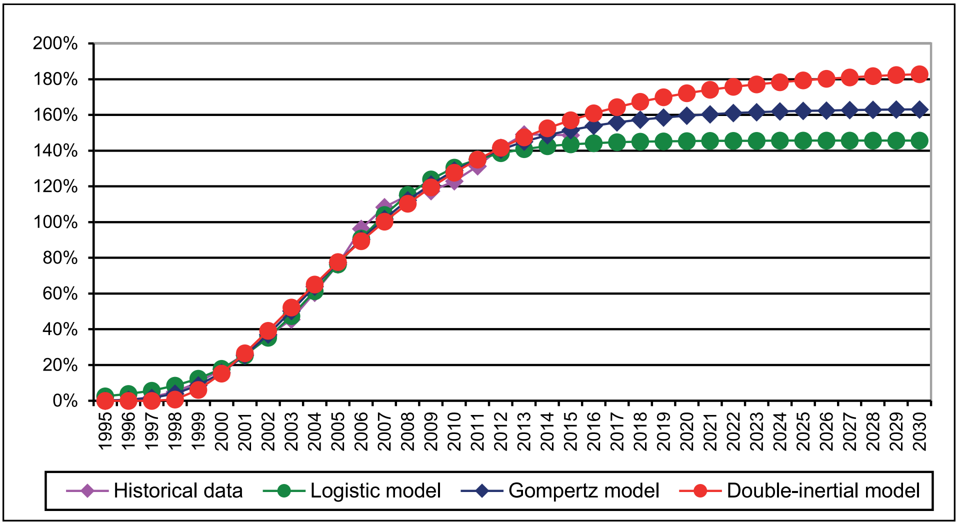


broadcasting, for example the invention of Guglielmo Marconi in 1895. However, the invention of a division of land into the (hexagonal) cells in which the corners are allocated antennas – which allows to cover the entire area for mobile telephony – occurred in 1943 for military purposes. Mobile telephony devices, however, were heavy, mainly due to the weight of the necessary batteries that powered these devices. Along with the use of transistors and integrated circuits, these devices have been progressively miniaturized, but the batteries remained heavy. Large corporations counted on dissemination of mobile phones; however, when in 1973 the heads of two corporations – AT & T Bell Laboratories and Motorola – demonstrated in a television broadcast cameras phones, they were kept barely in hand. Despite hopes connected with them, they did not achieve market success – because of both their still high weight (they were called brick-phones) and their excessive prices.

Only around 1990, the Finnish companies Radiolinja and Nokia, and after them quickly other corporations, marketed cheap versions of lightweight mobile phones, which led to their widespread social use. Counting from 1943 to the early spread of cheap and lightweight mobile phones, the delay of social use of mobile telephony amounted to approx. 50 years; the actual social dissemination was not saturated until today, hence the total delay is more than 70 years.

We see from Fig. 4 that we already account for more than one mobile telephony device for an average citizen of Poland, but forecasts of the saturation level of social penetration are diverse (from approx. 145% to 180%). This higher level is more likely, since the new mobile phone devices provide also Wi-Fi access.

Fig. 4. The spread of mobile telephony in Poland, approximating and forecasting curves (data until 2015).



The inventions preparing the Internet occurred also well in advance of the start of its social penetration. This was mainly the invention of hypertext, originally described in an article of Vannevar Bush *As We May Think* in 1945, then improved by several authors, until in 1992 Timothy Berners-Lee and his colleagues at CERN launched the first web server; which started a rapid spread of the Internet.

We see from Fig. 5 that over 60% of the Polish population has an access to the Internet, and the diversity of saturation levels in various projections (from 70% to 80%) again does not matter much, because of the integration of Internet access with mobile telephony which will change the saturation level.

4. Integration of waves and its social effects

At the moment, a far-reaching integration of all these four waves occurs: television, personal computers, mobile telephony and the Internet. New variants of mobile tablets and smartphones allow people to connect to the Internet, television, personal computer and mobile phone. These new versions of personal computers, smartphones and tablets are so cheap that some companies offering telecommunication services offer these versions for free as a part of their advertising services.

Larger smartphones, so-called phablets are adequate enough and their users do not need another in the form of a tablet. In addition, the tablets are not subsidized by the operators as smart phones that you can buy at a lower price (in fact,

Fig. 5. Internet penetration in Poland, approximating and predicting curves (data until 2014).

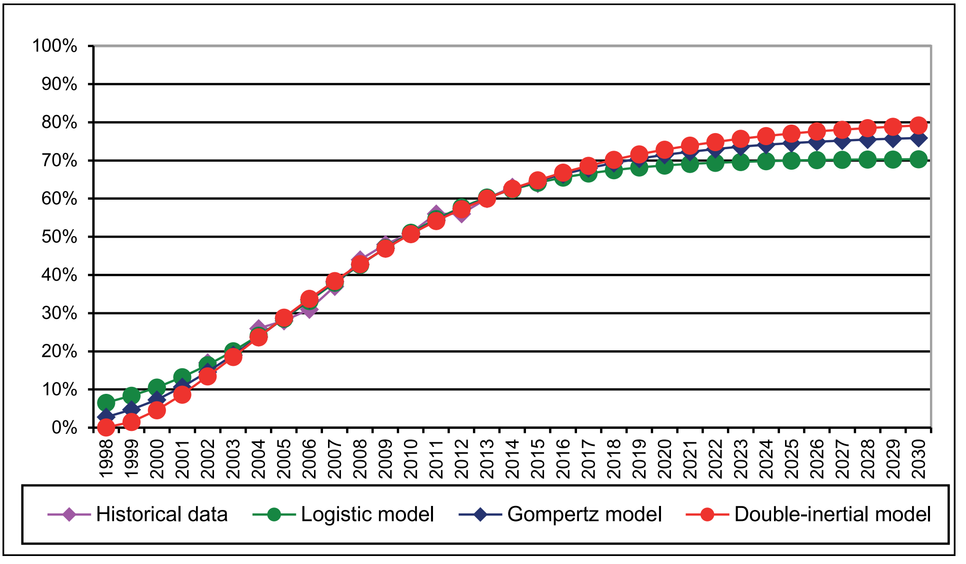
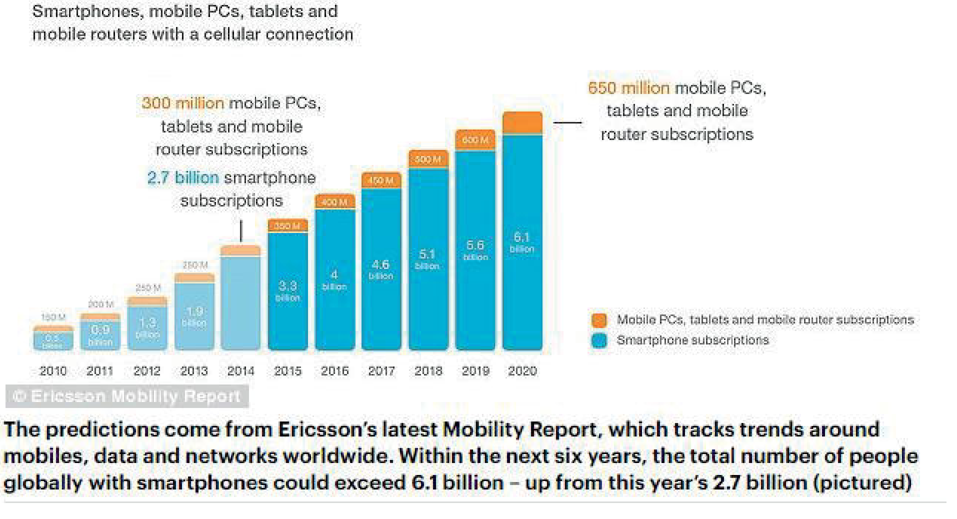


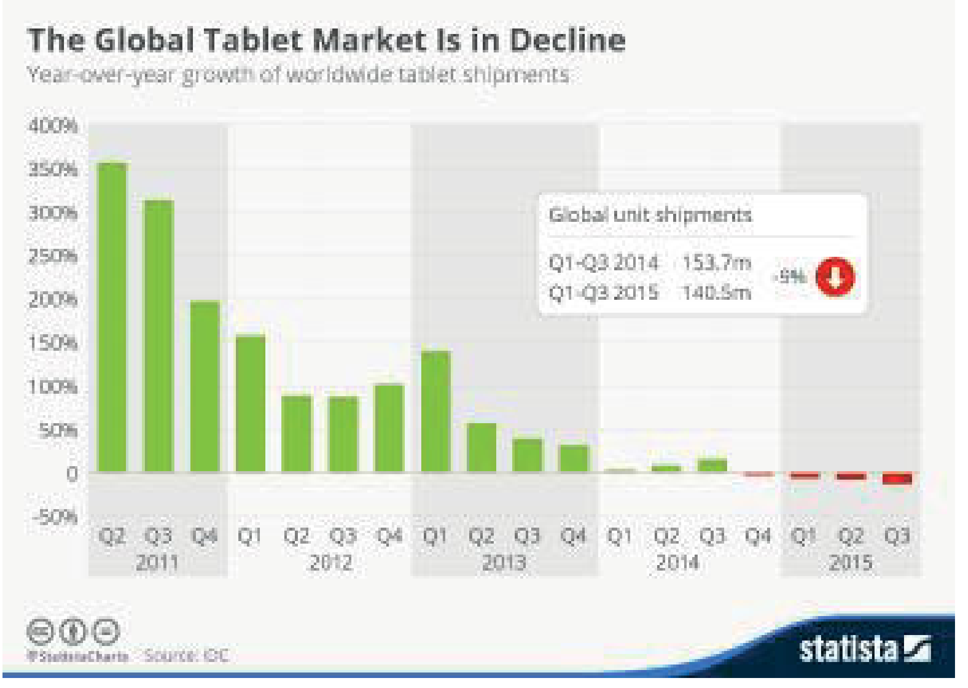
Fig. 6. The numbers of smartphones in the world [in millions] and their percentage share in mobile phones. According to eMarketer, December 2014



the operators include their costs in the cost of a subscription). Therefore, the tablet market saturation is faster than in the case of smartphones, as illustrated in Fig. 7.

The integration of television, personal computers, mobile telephony and the Internet through smartphones and phablets has a huge social impact. On the one

Fig. 7. Saturation of the global tablet market



hand, it is possible to easily obtain information of various types such as, e.g., satellite positioning, identifying variants of road connections, access to Wikipedia and other web sources of information. On the other hand, the possibilities of mobile television enhance both its positive aspects and the negative: media massage (McLuhan 1964) is strengthened, the spectacle society (Debord, 1967) embraces a growing part of the global society. Naturally, advertisers emphasize only positive aspects of their advertised products, thus the growing impact of advertising must lead to a deepening of the information asymmetry in the market. This is seen by all the people, but what most of them do not realize is the fact that advertising multimedia is significantly more influential on the subconscious of people, than the verbal text; this turn stems from the fact that the immanent human perception, with all senses, processes several hundred greater volume of information than the verbal perception of a text.

It is true that thanks to this integration the public all over the world is better informed; but at the same time the dominance of advertising tells the poorest parts of societies, how the richest layer of the most developed countries lives and what it consumes. This causes, on the one hand, envy and an increase of terrorist moods, and on the other hand, migration pressure to Europe and the United States of the better educated part of the population of the poorest countries. This pressure will even increase under the influence of coming waves of information revolution.

5. Upcoming waves: robots, knowledge engineering, biomedical engineering

The first industrial robot was constructed in 1957, although the concept of a robot is much older. Since that time the gradual replacement began of the work of the industrial proletariat by working stationary robots. While you can argue that the substitution of labor by capital (or rather the tools and machines acquired by capital) progresses from the beginning of the industrial revolution of the late eighteenth century, and so far did not necessarily caused unemployment, only significant changes in the structure of work. But such a statement is self-deluding, for two reasons.

First, the substitution of labor by capital is a process with positive feedback: the more a capitalist gains on investments in new machinery and equipment, the more he is willing to invest in them further. Processes with positive feedback have the nature of an avalanche: they may start slowly, but then inevitably accelerate. Replacing work in enterprises by capital takes place today at an unprecedented pace and scale, see (Wierzbicki 2015), and hence historical opinions are not valid today.

Secondly, since around 1980 the developed countries used also another mechanism of globalization, exporting jobs to developing countries with lower labor costs which caused the destruction of industrial proletariat in their own countries. However, since robots as well as other information revolution devices are steadily becoming cheaper, therefore the above-mentioned mechanism of positive feedback will result in the destruction of industrial proletariat and the end of the work in enterprises also in poorer countries. This will increase the conflicts in these countries and further increase the above-mentioned migration pressure.

However, the prevalence of robots in industrial work is not yet accompanied by a widespread prevalence of robots in society. Such widespread dissemination will start when robots will walk with us on the streets (such as mobile phones do today), or will replace us in the service work, as, for example, in supermarkets already occurs in Japan. So it is not a permanent, only a transitory truth that the work in services replaces the industrial work; work the work in services is already shrinking not only because of the use of robots and computers, but also through the use of network services.

The number of robots in the world and the resulting projections illustrate Figs. 8, 9. They show that approximately around 2050, the number of robots will outnumber the world population. Even if it is only an approximate prediction, there is no doubt, however, that robots will walk with us on the streets and replace people in most of service work.

A similar, though less widely perceived character has a further wave of information revolution, namely the wave of knowledge engineering that is often popularly (though inaccurately) called the wave of artificial intelligence, ambient intelligence (or smart homes), the Internet of things, etc. It is related mainly to the knowledge mining in large data sets that grow in the world at a rate resulting from

Fig. 8. The number of robots in the world by the International Federation of Robotics (IFR)

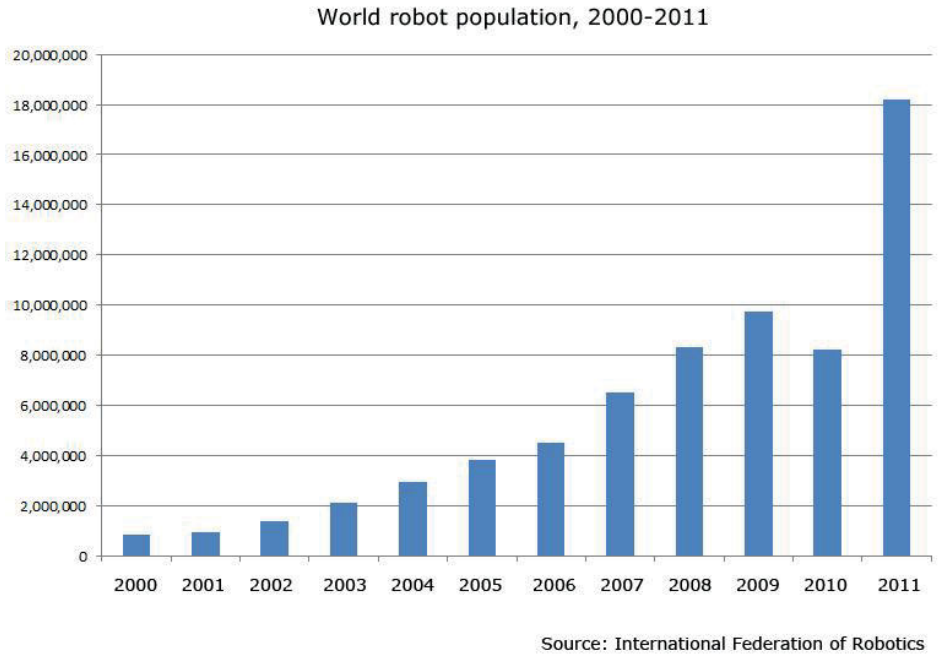
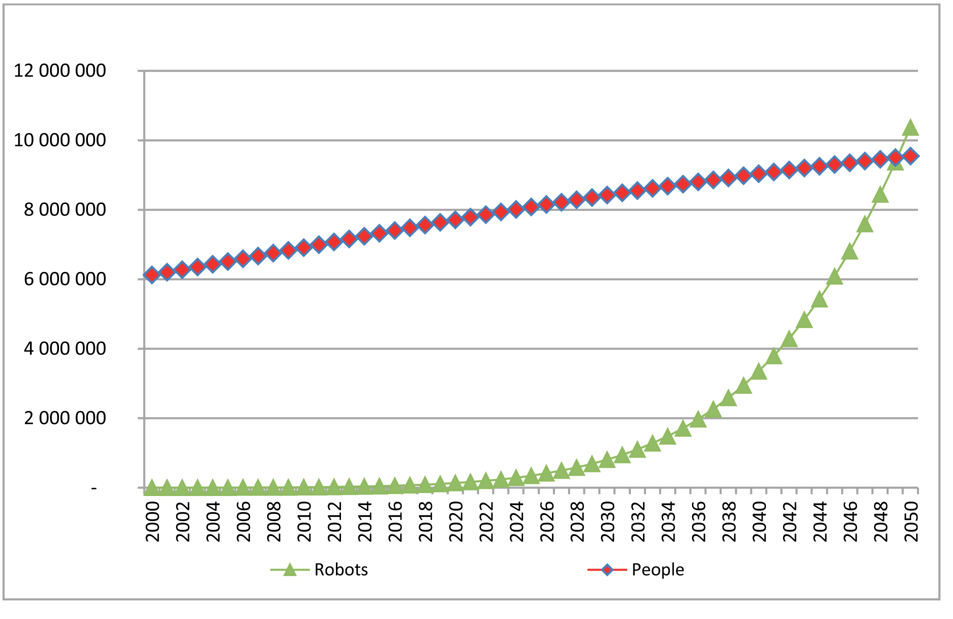


Fig. 9. The forecast of the evolution of the number of robots in the world.



Own prediction (using the Gompertz model) based on data from IFR the multiplication of the growth rate of computers used (at least two times every five years) and the growth rate of the capacity of computer memory (about ten times in five years in accordance with Moore's law, see Moore 1965); multiplying this rate, we conclude that the number of stored data in the world can be increased at least four hundred times in each decade. Analyzing such large data sets, we can draw most diverse conclusions and applications, although of course the current uses are mainly commercial in nature, e,g. related to targeting marketing campanges.

However, it is still hard to talk about the universality of the use of know-ledge engineering. Universal utilization will begin when software of knowledge engineering will be widely used in mental work, e.g., in automating office work. So far, state administration and local governments successfully defend themselves against excessive automation of their functions, so we should not expect a quick end of work in administration and in professions requiring personal contact, such as health care and teaching.

Another incoming wave, which has not yet reached the beginnings of a widespread use, the wave of biomedical engineering. Indeed, since the Röntgen (invention in 1895), increasingly more common is the use of various electronic methods of health care and research, but a universal and full use of information technology for the integration of such data and for supporting health services has not been achieved yet, see, e.g., (Granat and Klimasara 2014). This wave will also likely have serious social consequences.

6. Prognostic and general conclusions

The main conclusion of this article is the fact that the nature of social life will change in the coming waves of information revolution even more strongly than it has changed in the last thirty years. Especially dangerous is the process of positive feedback between the profits of businesses and achievement of high technology, especially in the wave of robotics. The processes of positive feedback speed up and end in hitting a constraint. A constraint in this case might be the end of work in enterprises and in services, which could cause serious social conflicts. It is therefore necessary to consider how to prepare society for the twenty-first century so fundamental and rapid changes in the structure of work. A serious reform of the capitalist system might be needed, based on the increased ethical requirements on businesses, as well as on a fundamental reform of the corporate tax system, see. Wierzbicki (2015).

Understanding the nature of the waves of the information revolution is therefore essential for understanding of future that awaits us. It follows that the students of all universities, including humanities, should be trained also in technical subjects related to the upcoming waves of information revolution: in robotics, computer science and engineering knowledge, finally in biomedical engineering.

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