Future of the information society and information technology from the 2005 perspective.

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Our *homo sapiens* species exists for several millions of years, but civilization is a very recent phenomenon. Agriculture and first permanent settlements started probably no more than 12000 years ago, and written sources cover only about 5000 years of human history. This time span could be covered by no more than 100 wise men passing their knowledge to the next generation. 500 years ago the world seemed to be full of witchcraft and magic because virtually no physical or biological phenomena were correctly understood.

50 years ago first commercial computer was sold and IBM predicted the demand for 3-5 such machines in the USA. 30 years ago the market for software did not exist and the president of Digital Equipment Corporation, producing mainframe computers, could not see any reason why someone would like to have a computer at home. 15 years ago the World-Wide-Web was a dream of a few physicists from CERN and until mid-1990s computer experts treated WWW as a kind of unimportant curiosity. Computers, software and the Internet are now major driving forces behind the prosperity of rich nations. Information technology (IT) develops at an accelerating pace and substantially contributes to the real economic growth of developed countries, in the USA being a dominant factor [1].

What are the long-term prospects of information technologies? How will our lives look 10, 20 or 30 years from now? We need a vision to prepare for opportunities and dangers awaiting us in the future.

A brief history

The second part of XX century has seen an unprecedented development of information technology. Quantum mechanics discovered in 1925 allowed for the development of physics of semiconductors that provided technological basis for construction of integrated circuits (in the year 2000 Jack Kilby got the Nobel prize in physics for this discovery). The future of all technological development depends on advances in solid state physics, nanotechnologies, quantum optics and other branches of physics. New hardware enables the development of new information processing software technologies that use more processing power, including software for design of better microprocessors, that in turn are used to design new hardware. Due to this positive feedback between hardware development and software used to design it this process is still in the phase of exponential growth, described by Moor's law.

Here are a few most important dates from the recent IT history [2]:

1978 First computer programs, VisiCalc (spreadsheet) and WordStar (word processing) started the era of application software.

1981 IBM-PC was introduced, starting the personal computer era;
first BITNET network nodes for e-mail and information distribution via listservers have been established.

1982 Introduction of communication protocols (TCP/IP) defined the Internet.

1984 Apple Macintosh with graphical user interface made computers friendly.

1992 WWW protocols were released by CERN, starting the Web era.

1993 Mosaic, first graphics WWW browser, was created at NCSA;
personal computers got enough power to support multimedia.

1994 US Government provided WWW information servers, and UK, Japan and New Zealand followed;
first Internet shopping malls and Pizza Hut orders were made;
first cyberbank was opened;
Internet radio stations started broadcasting.

1995 *Chinnok,* a checkers program, won the World Championship with Don Lafferty;
Cycorp, a commercial company developing expert system with encyclopedic knowledge based on over 1 million of rules, was formed after 10 years of academic research;
Internet companies went public.

1997 *Deep Blue* won with the world chess champion Gary Kasparov, showing AI potential; although the press wrote of enormous speed of the computer vs. human intuition in fact the machine had less than 0.1 % of the speed/memory of the human brain;
experiments integrating biological neurons and silicon devices were made;
telecommunication industry started the process of integration with digital media and the Internet, creating wireless WAP protocols.

1998 Computer-controlled car drove across the USA without human intervention;
databases started to accept orders given in natural spoken language;
navigation systems for cars used computerized maps and GPS;
hand-held wireless communication devices combining cellular phones with PDAs (Personal Digital Assistants) were introduced.

1999 *e*Europe EU initiative was started, a move towards information society, recognized Internet as a key factor for growth, competitiveness and employment;
Intel sales through the WWW reached 1 mld $/month;
supercomputers make about 10^{12} operations/second and use 10 GB RAM;
experiments connecting visual signals from camera to the brain were made;
ear implants connecting to auditory nerves become common;
direct connection to the primary visual cortex was used to send signals from camera;
successful transplantation of a monkey head was performed;
Sony introduced AIBO, an artificial dog toy with complex, adaptive behavior.

2000 PCs had enough power to support speech and visual object recognition;
household Web devices, such as refrigerators and microwave ovens, appeared;
computers integrated with jackets and shirts were shown (Levis and Philips);
experiments demonstrated technical feasibility of quantum computers;
AI techniques became common in many computers games;
robots designed by computer programs, build from parts by other robots, observed in an environment and automatically improved by evolutionary computer programs were reported;
recognition of human emotions and emotional responses of robots were demonstrated in the MIT AI laboratory;

0.5 mld transistors and 10 mld neurons were born every second; these proportions will soon be reversed – a cost of a single transistor in a chip is lower than a cost of printing of a single letter.

2001 First nanochips were constructed for experimental purposes;
3rd generation mobile phones were introduced in Japan; *Bluetooth* wireless technology connects all kinds of electronic devices;
human genome mapping has been finished with the help of sophisticated software;
spine implants increasing stimulation of the brain pleasure centers were offered;
real-time translation of spoken language via telephone with 90% accuracy was shown;
theories of metabolic and genetic processes in cells, too complex for a single human to follow, were captured in artificial intelligence software;
eel's brain has been connected and could control a wheeled robot; many research projects try to achieve communication between brains and machines;
recognition, expression and understanding of emotional behavior becomes, called affective computing, becomes mainstream subject in computational intelligence;
microprocessors with 170 millions of transistors were offered.

2002 NEC Earth Simulator computer reached 3.6×10^{13} operations/second;
sales of domestic robots have tripled in one year, for example Trilobite by Electrolux, an automated vacuum cleaner;
smart toilets that evaluate weight, fat, blood pressure, heart beat, urine sugar, albumin and blood in urine are commercially sold, plans to connect them to family doctors were unveiled;
experiments replacing hippocampus, large brain structure very important for memory consolidation and spatial orientation, in rat's brain;
"Enduring personalized cognitive assistant" (EPCA) project formulated by the DARPA agency, started in 2003;
almost all scientific literature may be accessed electronically.

2003 Third generation (3G) services and portable phones in Japan integrate with digital cameras, music and video players, and PDAs with wireless networking, enabling fast access to information through WWW;
Sony Qrio house robots were introduced, demonstrating great dexterity in sensomotoric skills that require solution to extremely complex control problems;
many web pages use talking heads to answer client's questions;
consciousness in artificial systems is a subject of vigorous research;
Worldwide sales of robots designed for domestic chores and for home entertainment exceeded for the first time sales of industrial robots (reported by the United Nations Economic Commission for Europe).

2004 Projects aimed at large-scaled simulations of the whole brain are formulated;
first electronic ink books appeared in Japan;
great progress in brain-computer interfaces has been achieved, with faster control by thought then control possible by physical movements;
Sony has patented direct brain-computer non-invasive interface, based on ultrasound projection to change neuron firing patterns.

2005 IBM Blue Gene architecture with 360 Teraflop speed, about 1/30 of the human brain;
many new humanoid robots are shown by Japanese and Korean companies;
Mitsubishi starts selling "wakamaru", the first humanoid robot in Japan that can recognize and speak to people, providing them with information from the internet.

The seeds for future development have already been planted. Hundreds of millions of computers are in use, creating a huge market for innovative software. Are we close to the limit of

computer development? No, in fact we have not seen much yet! The power of computers has been increasing exponentially, in agreement with observation made by Gordon Moore that every 18 month the number of transistors on a chip doubles. New applications require more computing power, memory and connectivity, and it is coming.

A short history of near future

At the beginning of XXI century many innovative IT programs have been launched in Europe. The *Future and Emerging Technologies* (FET), the EU 5th and 6th Framework subprograms supporting visionary, high-risk research, included "disappearing computers" that enrich the environment, augment everyday objects with IT and form collection of objects that act together, and "neuro-informatics for living artifacts", construction of hardware/software systems that adapt and evolve in a real world. Visionary projects, like "breading creative information societies in a global information ecosystems" have been submitted to the "global computing" FET call. Machines have already shown some forms of creativity [2][3] and in the next 10 years with the speeds of computers approaching the capability of human brains the notion of creative machines may become widely accepted.

Ambient intelligence will be almost invisible and ubiquitous, enabling natural interaction with IT systems at home, in the office and on the move. At home various ambient services will optimize energy utilization, provide information and learning materials, interactive entertainment, home banking, increased security and medical care, and connect with local shops controlling food supply. On the move smart car guidance systems already advice on optimal routes, receiving real-time information via Internet, increasing safety of driving and shorting traveling time. New tools will radically transform the office. 2005-2010 will be the period of creating IT infrastructure to support all these changes: new wireless networks, smart cards, portable devices, software and information content and services.

Future will bring many more radical changes. The seeds of future technologies already exist, although many new technologies should appear. Some technologies, such as the WWW and portable phones have been widely adopted in a very short time profoundly influencing economics of developed countries. In the years 2005-2010 in countries leading in technological development we may expect gradual spread of the following technologies:

- 3rd generation portable phones integrated with digital cameras, voice recorders, video and music players, and computers of the Personal Digital Assistant (PDA) type. This will enable fast access to information and services via Internet, cheap (sometimes free) global communication using voice-over-IP, and will give the ability to document daily life of people in increasing number of details, continuously recording voice and making digital photographs.
- Speech recognition technologies will be in use for communication with databases, slowly replacing the voice-mail systems in such tasks as making purchase orders or dictating texts in major languages. Speech recognition in smart phones will allow for quick crude translation between languages, making electronic translators easy to use.
- Computers integrated with clothing will become fashionable in rich countries.
- "Life shirts", smart toilets and other devices will monitor the state of our organisms, significantly contributing to health improvement by detecting the first symptoms of diseases.
- Electronic ink and polymer displays will show some impact on the printed media.
- Virtual reality games including 3D vision, hearing, tactile and olfactory sensations will appear in high-end games and commercial simulators.

- Augmented reality maps will be in use in some cities, providing personal navigation systems (similar to car navigation systems) that display 3D information on special glasses.
- Significant steps towards widespread use of videoconferencing systems and their improvements in the direction of teleimmersion (giving the participants an illusion of "being there") will be made.
- First home robots will be sold as human companions, caring for the elderly, security watching and cleaning houses.
- Simple dialog with computers running "common sense" software, with recognition of semantics, prosody and gestures will become possible.
- Personal avatars will arrive in new generations of phones, helping to control and program household devices and representing their owners in many situations.

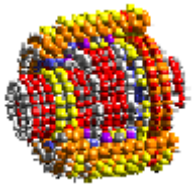
In the years 2010-2020 more profound changes may be expected:

- Supercomputers with speeds surpassing human brain will be in use for many projects requiring large-scale simulations.
- Most computers will work with natural language interfaces and will have common reason, allowing them to find information and answers to all kinds of questions by performing semantic analysis and finding relevant information sources.
- Media, telecommunication and information technologies will be unified. Communication devices will allow to quickly access any information thanks to intelligent browsers. They will also provide such services as live translation between natural languages.
- Some Internet servers will start to provide virtual reality content that will be viewed through personal glasses projecting the image on the retina. The body movements will be scanned to respond appropriately. The bandwidth for the very fast Internet access will be provided by the Grid infrastructure.
- Computers will become indispensable in making decisions in many fields, including economics and politics, because software simulations will allow predicting the effect of new laws and government actions.
- Most transactions will be done over the network between humans and avatars and many only between avatars representing humans and reporting to humans later; demand for avatar personality designers will be high and personal avatars, adapted to their owners, will appear playing the role of alter-ego.
- Intelligent tutorial systems will become a basis for education at all levels; education will be deeply transformed in view of quick availability of information.
- Artificial animals capable of recognizing and expressing emotions will be common although not perfect.
- Direct stimulation of various brain areas using implants will be frequently used for blind, deaf, crippled and violent people.
- Stimulation of the infant's brain will be used to facilitate optimal brain development and prevent developmental disorders; dyslexia, speech abnormalities, attentional problems and problems with learning foreign languages will be largely things of the past.

The speed of changes may get even faster in the next decade. After 2020:

- Computers based on nanotechnology sold for 1000 $ will offer speeds and memories comparable to that of the human brain and will have the ability to reason about all subjects, becoming indispensable advisors.

- Computers programs will make most decisions better than people, so in many respects they will serve as partners and advisors to people; the main computer interface will be based on artilects (artificial intellects) in form of personalized avatars.
- Artilects will pass Turing test in opinion of most judges, at least in text-based communication tests.
- Quantum computers with powers well beyond human brains may be used in some applications, solving optimization and other problems that are hard to imagine now.
- Computers will design and construct new, more powerful computers without help from humans, evolving on their own. Technology for building machines that behave in a conscious way will appear.
- Cyberspace will become the basic medium of communications where people will meet with each other and with artilects in virtual reality and teleimmersion sessions.
- Natural communication with artilects via gestures, anticipation and emotional face expressions will be available in cyberspace through personal info-devices.
- 3D glasses will give full illusion of visual reality and tactile interfaces should become common. Only small percentage of people will commute to work.
- Specialized robots of all kinds will be used everywhere and general-purpose robots should arrive at homes, offices and in workplaces.
- Ambient intelligence will be build into most objects of common use, including clothing, vehicles, house appliances and house construction elements (roofs, doors, windows).
- Direct communication with the brain using the extension of transcranial magnetic stimulation devices will enable extensions of sensory experiences and cognitive functions.
- Discoveries and theories will be made supported by computers as indispensable partners. Some discoveries will be hard to understand for humans because of our limited spatial imagination while others, especially in biosciences, will be too complex for our minds to comprehend in details.
- Nanotechnology will speed up the trend towards cyborgization of humans. Many artificial devices will be mounted in the brains of elderly people to enhance their perceptual and motor abilities.



By 2030 we may live in a science-fiction world:

- Computers costing around 1000$ with capabilities comparable to 1000 human brains will be sold. It is hard to imagine what will be their limits.
- Artilects will pass the Turing test, claim that they are conscious and this claim will be widely accepted.
- New knowledge generated by artilects will be beyond human understanding.
- All production and most services will be fully automatic.
- Most interactions in the cyberspace will take place between artilects developing their own interests and representing humans.
- Real 3D world will not be interesting for most artilects, further evolution will take place in high-dimensional spaces;
- Some humans will have significant parts of their bodies replaced by artificial systems.
- Even healthy humans will experiment with extensions to their brains.
- For people with implants virtual reality will be indistinguishable from real experiences.
- Technology for mind-sharing should appear (extension of empathy/imitation of the “mirror neurons” in the brain);

These predictions are based on extrapolations of technologies that exist already now. Today’s computers have sufficient power to perform at the insect brain level but this is changing

quickly. The actual dates are disputable but the trends are clear. It is impossible to predict what will happen once computers will become smarter than man and will start making discoveries to fulfill their own curiosity. Although there are many books claiming that artificial systems will never be able to compete with humans in making discoveries (cf. [5]) they are based on misunderstandings and wishful thinking rather than on real technological barriers. Arguments based on Gödel theorem are frequently used, but all they show is that there will be some questions related to formal specification of deterministic computer, that this computer will not be able to answer. Human brains are also not capable of answering questions related to their own specification, and even much simpler questions are simply to complex for us to answer. Such theorems simply prove that it is impossible to build a machine which will know everything, but do not place any "sub-human" limits on the level of intelligence that the machines may eventually achieve.

AI programs based on an idea that "interesting" means "simple and allowing for many conclusions and associations", have already been used to simulate curiosity in mathematics. Robots based on very general values, such as "it is good to have experiences" have been constructed and have spontaneously developed many interesting behaviors [4]. The main problem is to build and train systems that have sufficiently complex and rich internal representations that will allow them to do things interesting for humans. Are we capable of creating such systems? Is human mind able to understand itself? Building flying machines did not require understanding of all the details of bird's aerodynamics and constructing thinking machines is not different. General principles are understood now sufficiently well and each generation of new computers and software provides the tools allowing to design better systems in a bootstrapping process. We are now at the point of making this process automatic using ideas based on natural evolution. In this way the evolution of intelligent machines may recapitulate the evolution of humans but it will happen millions of times faster.

Dangers and opportunities

Biotechnology and information technology may create in the near future fantastic, transhuman possibilities, but technology by itself will not bring us happiness. The lack of imagination of science-fiction writers and movie makers is obvious: they put a savage, cruel and aggressive man in space ships, assuming that all man wants is power. To avoid such future, understanding of the real needs of humans and creating human-centered technology is of utmost importance. Man creates technology and is changed by it at the same time, but is it a change in a desired direction? Is information technology fulfilling our needs? Many gadgets are produced in hope that some will become fashionable, but do we really need them? Cognitive technology, adjusted to the human information processing capability and based on understanding of human needs, should replace the traditional approach of the technocrats.

We have learned to pay attention to the environment, but only to the external environment. What we need is a new ecology of mind, teaching children how to protect their brain. There is no doubt now that the mind is a function of the brain. The damage to the brain cripples the mind, cripples human soul. This damage is inflicted on the brain by traumatic childhood experiences, drugs and other addictive substances, but also by media that create an artificial and distorted view of reality. In the past minds were formed in stable environments, observing real events and reflecting on them. Nowadays it is the media that form our minds, information is composed almost entirely of exceptions, unusual or odd events, showing death and violence, distorting perception of reality. How should our brains be protected from harmful influences

that information technology is only going to amplify? What should be done to facilitate the full development of individuals?

Changes brought by technology are so fast that societies have no time to adjust themselves to new situations. In the past societies were stable, people had well-defined professions that were practiced through all their lives, mortality of infants and children was very high leaving only the most healthy and well-adapted individuals. Societies had sufficiently long time to adjust to slow changes. This has completely changed in the last half-century. Societies are paying now a high price for the rapid development since not all people are able to learn new professions when the need for their old skills fades away. How to minimize the social costs of the coming changes? How should we prepare for the life-long learning and the lack of stability of the future society? How will the structures of the society change when most of the human needs will be fulfilled by artificial systems? What will happen if only very little work will be left for humans? How will the cyborgization of humans by information and genetic technologies influence human race? Will robots in the long-term eventually succeed us [6][7]? Self-replicating technology, used now to create computer viruses, may also be used in robots and genetically modified organisms, brings with itself new dangers that can easily get out of control. The risk of potential misuse of such technology is much greater than the risks associated with traditional weapon technologies.

Many social and political decisions are taken already now after extensive computer simulations, trying to predict what the results will be. Such simulations will become indispensable and expert systems on social issues will sooner or later take better decisions than human experts. At some point of the development we will have no choice but to rely on decisions taken by machines to solve complex social and political problems. Human control will be restricted to high-level choices only. Some people fear [8] that this may make the masses of people superfluous and leave the elite with the enormous power.

We have many questions and very few answers. Politicians are not interested in a long-term strategy of development. The future may catch us completely unprepared.

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