Future Trends in Computational Intelligence from the 2012 perspective.

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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.

About 60 years ago first commercial computer was sold and IBM predicted the demand for 3-5 such machines in the USA. 40 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. 25 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 (Jorgenson, 2005).

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.

The glorious past

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.

Older development of information technologies is described in my books (Duch, 1997). Here are a few important dates from the recent IT history.

1970-73 Cybersyn project in Chile was the first exercise in real-time cybernetics control of the whole country economy.

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) that 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; the idea of the "Internet of things" - uniquely identifiable objects (things) and their virtual representations in an Internet-like structure – has been proposed and is slowly growing in importance; Intel sales through the WWW reached 1 mld $/month; supercomputers perform 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 have 1GHz clocks and 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 have soon 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; microprocessors with 170 million of transistors were offered; 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. Wikipedia is lunched.

2002 NEC Earth Simulator computer reached 36 trillion operations/second; sales of domestic robots have tripled in one year, mostly due to an automated vacuum cleaners such as Trilobite by Electrolux; 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 was formulated by the DARPA agency, started in 2003; almost all scientific literature produced in the world may be accessed electronically, changing the way science is done.

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). MySpace, first widely successful social network, is lunched.

The Human Genome Project is completed after 15 years.

2004 Projects aimed at large-scaled simulations of the whole brain are formulated; first electronic ink books appeared in Japan; 1GB memory cards are introduced; 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; DARPA Grand Challenge competition for driverless cars is organized in Nevada desert, but no cars can complete it.

Facebook is lunched, Web 2.0 emerged, allowing for active participation, not only consumption of content.

2005 IBM Blue Gene supercomputer was demonstrated with 360 Teraflop speed, about 1/30 of the human brain; YouTube was lunched; flash drives replace floppy disks; 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; DARPA Grand Challenge 240 km track was successfully completed by 5 cars.

2006 Twitter is lunched; online gaming is in full swing; cheap, flexible electronic skin twice as sensitive as a human fingertip demonstrated (Univ. of Nebraska). SpiNNaker project started construction of spiking neural architecture with the goal of one billion analog, low power neurons by 2014.

2007 Apple iPhone makes smart phones popular; Amazon popularizes e-books with Kindle; Google introduces street view in their maps; DARPA Urban Challenge 96 km finished by 6 teams.

2008 Google index surpasses 1 trillion unique URLs, several billion webpages per day are added; Internet has about 1.5 billion users, most use mobile devices; social networks are rising quickly, social bookmarking appear; efficient wireless energy transfer was demonstrated by Intel; Image Metrix shows almost perfect real time animation of human faces; military computer "Roadrunner" achieves Petaflop speed.

2009 Brain-computer interfaces sold as game controllers (Emotive); 3D scanners on the market; Avatar movie popularizes 3D technology, new TVs requiring glasses to see 3D pictures are on the market; cloud computing gains popularity; Human Connectome Project launched to map brain connectivity of 1200 adults.

2010 Apple introduces the iPad, tablets become popular changing the way computers are used; augmented reality applications appear in mobile devices; speech-to-speech translation appears in phones and tablet applications with touch-based interfaces.

2011 IBM Watson wins with two best human experts in Jeopardy (va banque); first commercial quantum computer sold (D-wave Systems); in Nevada driverless cars are admitted (Google cars project); free education by top universities becomes available on a global scale: in the first year Coursera (Stanford initiative with 11 top universities) had over 1.6 million course enrollments with 680,000 students from 190 countries; Udacity (Stanford) and edX (Harvard and MIT) collaborations follow; about 12 million personal service robots are sold worldwide; Quantified Self movement of people interested in self-tracking to learn more about themselves is gaining momentum.

2012 Microprocessors with 2.5 billion transistors, and FPGA with 10 billion transistors are in use; Intel chips with 3D technology and 22 nm structures are in many computers; Windows 8, radically new system from Microsoft, is released. New technologies (Nanopore) allow for fast analysis of whole genomes. Coursera had over 1 million students from 196 countries. Voice commands and Question/Answer systems (Apple Siri, Ask Ziggy, Google Voice, Utter and others) are used on a large scale.

The seeds for future development have already been planted. Billions of computing devices 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. Prospects for the electronics industry are still good. Every year since 1999 the International Technology Roadmap for Semiconductors (ITRS) publishes detailed analysis of trends in this area. New applications require more computing power, memory and connectivity. The cost of hardware per function (speed, memory, pixel density) has been dropping by over 25% each year, semiconductor market was growing by about 17% per year, and although a bit slower growth may be expected in the next decades due to the difficulty in building hardware at the nanoscale Moore's Law should essentially be unchallenged.

Imaginary short history of the 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 Science 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 (Duch, 2007) and in the next 10 years with the speeds of computers approaching the capability of human brains, and new software mimicking some cognitive processes, the notion of creative machines may become widely accepted.

6 candidates for the Future Emerging Technologies (FET) Flagships Projects, each with a 10 year 1 billion EUR programs, were selected and given funding for the final preparatory phase. 2 of these projects will be selected funded starting in 2013. These projects should give a boost to develop new directions in computational intelligence in the near future.

The first project is aimed at development of graphene science for Information and Communication Technologies (ICT), including novel materials and branches of science, such as spintronics, photonics, plasmonics and microelectromechanical systems (MEMS). The research on new hardware based on carbon is already well founded, with the electronic giants heavily investing in graphen. IBM has shown in 2011 an experimental graphene-based transistor operating at 100 GHz. Introduction of 3D technology combined with progress in nanotechnology led the ITRS group to predict that by 2020 structures of integrated circuits will be smaller than 10 nm, memory chips will reach terabits, and the density around 30 billion transistors per mm^2 will be reached. The brain has no more than 10^{11} neurons in about 1 dcm^3, so in one cubic millimeter we have about 10^5 neurons. The density of transistors in 3D structures will be greater by one to two orders of magnitude than the density of neurons. Assuming that each neuron has on average 10^4 connections in one cubic millimeter there is about one billion connections. Transistors have low connectivity, but even assuming that they have a single connection electronics will have an order of magnitude more connections than brains.

This is a conservative estimate and carbon nanoelectronics, optoelectronics, spintronics and finally quantum computing may increase available computing power significantly.

Quantum computing also seems to be making progress. Although D-wave Systems company has sold their experimental 128-qubit D-Wave One Adiabatic Quantum Computer to the Lockheed-Martin research center the era of real applications has yet to come. In February 2012 IBM scientists announced several breakthroughs in quantum computing, claiming that they are "on the cusp of building systems that will take computing to a whole new level". If successful quantum computing will exponentially increase our ability to optimize and simulate many processes beyond what classical computing may ever achieve, solving some NP-hard problems in polynomial time.

What can be done with such computing power? Several possibilities are outlined in other five FET Flagship proposals.

FuturICT: Knowledge Accelerator and Crisis-Relief System: Unleashing the Power of Information for a Sustainable Future.

The authors asked "What if global scale computing facilities were available that could analyze most of the data available in the world?" They envision building "The Living Earth simulator" that will be used to predict human interactions, travel, migrations, economic activity, climate, geophysical processes on the planet Earth. Through these simulations we should be able to understand and manage global systems, avoid crisis situations, reach sustainability and resilience. This requires integration of complexity and social science with information and communication technology. Over 300 international teams expressed their interest in this program.

ICT technologies have also growing influence on medicine. The third of the selected FET Flagship proposals is called ITFoM: The IT Future of Medicine. Medicine of the future will be based on the data obtained for individual people on the molecular, physiological and anatomical level, so it will be data-driven and individualized. This requires not only development of computational models of genes, proteins, human tissues, whole organs, signaling pathways, reaction to pathogens, spreading of diseases, the whole animal and human organism. Also experimental techniques have to be developed that will allow for quick scanning of the body, including whole genome analysis, followed by changes in health services and training of medical personnel. This is a challenge at unprecedented scale, but it can be met in 15-20 years if sufficient funds will be devoted in this direction.

HBP-PS: The Human Brain Project, is restricted to simulations of the brain only, not the whole organism. Understanding how the human brain works is of course very important for medicine, in view of the growing costs of the mental disorders and brain-related diseases that has reached in 2010 according to the report of the European Brain Council about 800 billion euro in Europe alone (Gustavsson et al 2011). Several large-scale projects t oreverse-enginnering human brain are already in progress. SyNAPSE: Systems of Neuromorphic Adaptive Plastic Scalable Electronics, develops electronic neuromorphic technology that should scales up to biological levels. The project is coordinated by IBM Research (Almaden), with many subcontractors. So far USA Defense Advanced Research Projects Agency (DARPA) contributed over 40 million dollars to the project that in 2011 has entered in its second phase. SpiNNaker, or Spiking Neural Network Architecture, should have in 2014 one billion analog, low power custom designed neurons. Simpler architectures have already been used to control robot movement.

The impact of understanding the brain and simulating mental processes may go well beyond medicine alone. Cognitive technologies inspired by understanding of natural perception will be developed, with speech and computer vision enabling natural communication with knowledge bases. Already now smart phones use chips for speech-background noise segregation working on principles derived from reverse engineering of auditory pathway. Brain-like chips define a fundamentally distinct form of computational device. Confluence of humans and computers is a topic of a new European initiative prepared for the "Horizon 2020" framework.

Complex cognitive technologies inspired by brain function will contribute to strengthen economy of the developed countries, as can be observed now with mobile technology. Better brain-computer interfaces are key to its development. Perception is already enhanced in many way thanks to the ICT artefacts, including direct stimulation of auditory and visual nerves.

Introduction of Google glasses in 2013 will make the trend towards augumented reality much stronger, with continuous access to information and presence in social networks.

Computer vision and progress in artificial muscles and control of manipulators with many degrees of freedom will have strong influence on robotics and further automatization of many tasks. Car driving in the next 15-20 years will be entirely done by automatic systems, for the long-distance transportation as well as for the home use.

Such devices are going to change the way brains develop and function. Social changes may be quite profound. Improvement in decision support, knowledge representation and creativity may help in developing artificial intelligence to the point where it could surpass human abilities. Combined with new computing technology (quantum?) this could help to solve many problems facing the world, but also to create a dangerous singularity.

The **Guardian Angels for a Smarter Planet** project is aimed at providing ICT support to assist people, especially older people suffering from various disabilities. Although the focus in many current programs is on helping in independent living of the rapidly growing number of old people, guardian angles should be deployed from infancy. Large percentage of children suffer from various developmental problems, from very serious such as autism to mild dyslexia. Permanent monitoring of babies and guiding their perceptual and cognitive development would certainly be of great benefit. Human Centered Technologies (HCT) should be developed to help control one's own behavior, overcoming addictions, flaws of character, depression and other mental disorders, maintain better self-control, increasing creativity, empathy, decrease impulsive behavior, learn to optimize long term behavior. Although these things are within reach of technology a concentrated effort would be required to develop them, as they may not lead to short term applications and thus may be difficult to find funding.

This Guardian Angels project will benefit from development of hardware, understanding such brain diseases, aging and dementia, but also from the general development of ambient intelligence, connecting various artifacts and making them smarter, easier to identify and use, and collaborating with each other in autonomous fashion. Part of this infrastructure development is connected to the "Internet of things" projects that should create ambient intelligence, adding tags to all objects, improving health care, food security, transport and logistics, security, and through geolocation that is already common in smart phones, car guidance systems and digital cameras, locating and recognizing people and places. Natural interactions through the ICT with people and objects at home, workplace and in the public places will make the environment intelligent, optimize the use of energy, security, medical care, provide all kinds of information including educational materials, access to social networks with telepresence, interactive entertainment, financial services and shopping. Automatic cars will find optimal routes and provide mobile access to the network, allowing to work and relax on the way. IT infrastructure to support all these changes is now being developed and it includes new wireless networks, smart cards, smart mobile devices, software and information content and services. Translation services allowing speech to speech translation are already being introduced and will be quite common after 2020.

Large-scale projects aimed at development of smart cities of the future are already in test phases in Europe and Asia, IBM is promoting their Smart Planet initiative. Analysis and understanding of sensor network signals is of primary importance in these projects. Tianji Eco-City is being developed by Singapore and China, and in the mid-2020s it should have 350.000 inhabitants. In the next decade cities may become guarding angels of their citizens, helping them to move around, find places, protect environment, watching their health.

In the next decade this will extend from interaction with local environment to telepresence and ability to remotely control most objects at a distance.

The CA-RoboCom: Robot Companions for Citizens, is another candidate for the FET Flagship project. The robotic companions envisioned here should deliver all kinds of assistance to people. Although the project is focused on humanoids, “soft skinned and sentient machines”, it should advance multidisciplinary science and engineering of cognitive robotics.

In fact all these projects together show interesting and overlapping possibilities for great development. They have a chance to bring many breakthroughs and address global challenges facing humanity. Some of these developments will come in smaller steps. In the next 10 years one may expect:

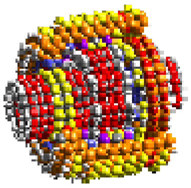
- Speech recognition technologies are already used in cars and smart phones, dictating texts in major languages, and to some degree are used for communication with databases. Speech recognition in smart phones allows for quick crude translation between languages, making electronic translators easy to use. They will gradually replace voice-mail systems in such tasks as making purchase orders.
- Ebooks already show some impact on the printed media, in the USA in 2011 ebooks had more than 10% market share, and in academia they start to dominate. In 2015 predictions in the USA ebooks should take 35% and in the UK 21% of the sales volume. They are read on the ebook readers with electronic ink and polymer displays or tablets. In many developing countries textbooks are offered on tablets. TechCast estimates that online publishing will approach 30% adoption of newspapers, magazines, journals, and other content already at the end of 2013.
- Computers integrated with clothing may 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.
- Virtual reality games including 3D vision, hearing, tactile and olfactory sensations will appear in high-end games and commercial simulators. Virtual Reality should be rather common before the end of this decade.
- In graphics the line between what appears real and what is merely computer rendered may be blurred completely by 2020.
- Personal avatars will arrive in new generations of phones, helping to control and program household devices and representing their owners in many situations.
- 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.
- 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.
- 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 the end of this decade strong confluence of humans and computing devices of all sorts should be expected. Combined with the voice recognition, question answering systems, the "Internet of things", this will empower users to control their environment in unprecedented way. Digital doppelgängers and avatars will not only represent us in various situations, but will have subtle influence on human personality, overcoming intimidation and changing behavior of their owners, who will learn about themselves using "quantified self" approach based on self-tracking their behavior with different sensing devices. This may be used to social advantage by providing good examples of personalities worth learning but it may also lead to unstable personalities. Avatars may be used as teachers on massive scale, radical transformation of education changing the way university diploma are perceived should be expected.

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. Penrose 1995) 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 (Edelman 1992). 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 replace us (Morvec 1999; de Garis 2005)? 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 (Joy, 2000) 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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