Part MMDXV

Future in the informatics era - Chapter 4

Chapter 5: PERCEPTION of INFORMATICS

TECHNOLOGICAL and APPLIED

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DEEP THOUGHTS

- The forces unleashed by the scientific revolution of the seventeenth century and the industrial revolution of the nineteen century helped to create the modern world.

  D. E. Stokes, 1997

- It is obvious that most of the basic secrets of nature have been unravelled by men who were moved simply by intellectual curiosity, who wanted to discover new knowledge for its own sake.

  The application of the new knowledge usually comes later, often a good deal later; it is also achieved by other men, with different gifts and interests.

  Murray Committee Report, 1957

VANNEVAR BUSH's VIEW

In late 1944 president of USA, F. D. Roosevelt, asked Vannevar Bush, director of wartime *Office of Scientific Research and Development* to look into the role of science in peace time.

Bush's committee created a report "Science, the Endless Frontiers" that influenced the development of science, world-wide for the next 50 years. Some of the ideas of Bush:

- Basic research is to be performed without thought of practical ends.
- Basic research is to contribute to general knowledge and an understanding of nature and its laws.
- Basic research is the peacemaker of technological progress.

After 50 years it has turned out that a fresh view on the relation between science and technology is needed.

DIFFERENT VIEWS and OBSERVATIONS - I.

Relations between science and technology keeps being explored since "second industrial revolution" and new views have emerged:

- It started to be clear only after the "second" industrial revolution in the late nineteenth century that technological progress may much depend on advances in science.

- That was due to the fact that the technical progress in chemical dyes and electrical power as well as in public health depended on advances in chemistry, physics and biology.

DIFFERENT VIEWS and OBSERVATIONS - II.

- Rapid development of technology in second half of 20th century made quite clear two points:

  1. Many advances in science were initiated by advances in technology (microscope, telescope, computer).
  2. Many big advances in technology have not been initiated by advances in pure science, but due to small advances in technology or due to huge demands of society/market.

SCIENCE versus TECHNOLOGY

- The origin of science is usually traced back to Greek times (600-300) BC. The modern concept of technology came into common use only in the ninetheen century.
- Relation between basic science and technology assumed its modern form during "second industrial revolution".
- Basic position is that
  - Basic science concentrates on understanding
  - Applied science and technology concentrates on use
- Since that time
  - Technology becomes increasingly science based.
  - The choice of problems and conduct of research are increasingly inspired by societal needs.

Informatization of all sciences and technologies blurs up differences between science and technology.

Basic task of modern universities.

To disseminate knowledge

Basic task of research universities (20th century)

1. To produce knowledge
2. To disseminate knowledge

Current tasks of top universities (21th century)

1. To produce knowledge
2. To disseminate knowledge
3. To put knowledge into a use

NEW PERCEPTION of INFORMATICS
- SUMMARY from CHAPTER 4

Informatics has four very closely related components:

- scientific,
- engineering,
- methodological,
- applied.

SCIENTIFIC INFORMATICS - briefly

The main scientific goal of *Informatics* is to study laws, limitations, paradigms and phenomena of the *information worlds*.

INFORMATICS as a FUNDAMENTAL SCIENTIFIC DISCIPLINE I

As a scientific discipline of a very broad scope and deep nature, Informatics has many goals. Its main task is to discover, explore and exploit in depth, the laws, limitations, paradigms, concepts, models, theories, phenomena, structures and processes of both natural and virtual information processing worlds.

To achieve its tasks, scientific Informatics concentrates on developing new, information processing based, understanding of the universe, evolution, nature, life (both natural and artificial), brain and mind processes, intelligence, creativity, information storing, processing and transmission systems and tools, complexity, security, and other basic phenomena of information processing worlds.

INFORMATICS as a FUNDAMENTAL SCIENTIFIC DISCIPLINE II

In order to meet its goals, the scientific Informatics develops close relations with other sciences and technology fields - currently especially with Physics, Biology and Chemistry, on one hand, and with electronics, optics, nano- and bio-technologies on the other hand.

The basis of the relationship between Informatics and the natural sciences rests first of all on the fact that information carriers are always elements of the physical, biological or chemical worlds, and consequently information processing is governed and constrained by their laws and limitations. Of importance is also that information processes are an inherent part of the basic aspects of the nature and life.

INFORMATICS as a FUNDAMENTAL SCIENTIFIC DISCIPLINE III

Informatics as a science includes numerous theories needed for its development to depth and in broadness. Some theories are abstract, others quite specific, and some theories are oriented on making better use of the outcomes of the scientific Informatics to create a scientific basis of technological informatics and informatics-driven methodology.

To meet its scientific goals, Informatics has to develop a whole variety of subareas. Some are deeply abstract and appear to be, at the first sight, quite remote from the main tasks and interest of the current engineering or applied Informatics, yet they serve to develop deep insights into the key problems and powerful conceptual tools

INFORMATICS as a TECHNOLOGY DISCIPLINE

MAIN DRIVING FORCES of TECHNOLOGICAL INFORMATICS - I.

- Military interests (design and testing arms, modelling and simulation of combats strategies, unmanned planes, intelligent weapons, fighting robots, surveillance techniques, ...)
- Modeling and simulation of complex and huge universe, nature, life and society real and virtual processes.
- Top science and technology projects (space travels, cosmology, high energy physics, cells and molecular research, brain and genome sequencing research,...)
- Medicine and health care (models of human bodies, design of nanobots, to fight diseases and death, to make hume life much longer, active and healthy, to develop drugs.

MAIN DRIVING FORCES of TECHNOLOGICAL INFORMATICS - II.

- Top science and technology projects (space travels, modeling huge nature ohenomena, brain and genome sequencing research,...)
- Needs to build computer with information processing power larger than that of humans brains.
- Needs to improve and overcome human intelligence, creativity, sensing,...

MAIN DRIVING FORCES of TECHNOLOGICAL INFORMATICS-III.

- Attempts to design global computer and communication networks.
- Attempts to learn from nature how to do information processing.
- Attempts to make new generations of WWW.
- Attempts to keep validity of Moore law in general, and to develop exascale and more powerfull computing in particular.

INFORMATICS as a TECHNOLOGY DISCIPLINE - short description - I

As a technology disciplines, Informatics concentrates on the design, analysis, validation and verification of the natural and men-made devices used for acquiring, mining, storing, structring, processing, transmition and vizualization data, information and knowledge.

Informatics as a technology discipline concentrates, currently, mainly on the development of elements/components, hardware and software architectures and systems for storage, computations, communications, networks, visualisation, robotics and wide range of services.

INFORMATICS as a TECHNOLOGY DISCIPLINE - short description - II

Informatics as a technology discipline concentrates also on theories and methods of information processing and communication systems specification, correct and efficient design, implementation, analysis, verification, evolution, evaluation, maintenance and utilisation.

Concentration is mainly on the development of the underlying theories, methods and tools that are either quite universal or at least relevant to many applications.

INFORMATICS as a TECHNOLOGY DISCIPLINE - short description - III

Scalability, availability, reconfigurability, persistence, sustainability, performance, reliability, safety and privacy, as well as assimilation of new supporting technologies, are some of the key issues.

As a technology discipline, Informatics concentrates:

- On the specification, design, analysis, validation, verification and maintenance of natural and especially human-made (hardware) devices and (software) systems used for acquiring, mining, retrieving, storing, processing, imaging and transmitting data, information and knowledge.
- On the development of tools and methodologies (for example specification and programming languages, methodologies and systems) to make an efficient use of such devices and systems.

INFORMATICS as TECHNOLOGY IN MORE DETAILS - II.

Technological informatics concentrates much also on the design of more and more intelligent information processing systems and robots that could either simulate or even outperform living beings and especially humans in various body or mind activities.

Information digitalization and (structured and concise) representation; abstraction representation and structuring; designs specification, developments, analysis, validation, verification, maintenance, and so on are some of the main tools of technological informatics.

INFORMATICS as TECHNOLOGY IN MORE DETAILS - III.

Informatics as a technology discipline concentrates, currently, mainly on:

- The development of elements/components, hardware and software architectures and design methodologies as well as systems for storage, computations, imaging, reasoning, (human-machines and machines-machines) communications, networks, internet and web systems and services;
- Social networks and their services, visualisation, images representation, creation as well as manipulation of computer graphics and animation systems, as well as wide range of other services.

INFORMATICS as TECHNOLOGY IN MORE DETAILS - IV.

Transistors, VLSI technology, design platforms, chips, CPU, memories (RAM, special memories, memory discs, ...), peripherals, graphic and other cards, drivers and microprocessors are some of main hardware elements. Pipelining, multicore memories, parallelism, concurrency and networking are some of main information processing modes. Interface cards, switches, repeaters, bridges and routers are some of main networks components.

Operating systems, database systems and compilers are some of the major general software systems. Programs, protocols, syntax, semantics, types, objects, agents, clients are some of the key software concepts.

INFORMATICS as TECHNOLOGY IN MORE DETAILS - V.

Design techniques (from requirements specification) and their (mechanized) support, documentation, architecture, verification, maintenance, portability, reliability, robustness, security, machine independence, reusability are some of the main issues concerning software systems.

Informatics as an engineering discipline concentrates also on theories and methods of information processing and communication systems specification, correct and efficient design, implementation, analysis, verification, evolution, evaluation, maintenance and utilisation.

Scalability, availability, adaptability, persistence, sustainability, performance evaluation, reliability, virtualization, safety and privacy, as well as assimilation of new supporting technologies and a symbiosis of information processing devices and humans, are some of the key issues.

Miniaturization, low-power consumption, design platforms, significant increase in performance and reliability, and bio-inspired devices are some of other current concerns.

Information processing on atom and molecular levels as well as petabytes and exaflops computing are some of the main current goals.

INFORMATICS AS a LEADING TECHNOLOGY DISCIPLINE

- Without much exaggeration we can say that we are facing economy in which computing is central to innovations in nearly every sector.
- Indeed, it would not be an exaggeration to say that every significant technological innovation of the 21st century will require to use some, more or less sophisticated, informatics concepts, methods and technology.
- In the past, but far, far less, such a leading role had steam engine technology and later electricity based technology and their corresponding scientific bases.

GRAND CHALLENGES

TECHNOLOGICAL INFORMATICS

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS I. - briefly

- To achieve sufficient security and reliability of huge information processing systems and networks.
- To develop methodology for ddesign of powerful superintelligent systems.
- Verifiable designs of huge, distributed and reliable information processing systems.
- Integration of heterogeneous ICT technologies.
- Steady minimization of size and energy consumption and maximization of information processing systems performances - to give long life to Moore law.
- Design of a global computer (network) - cloud computing
- Design of micro- and nano-scale (nano)robots.
- Bio- , cells-, molecule- and brain-inspired computers
- Systems (robots) beating (very much) human intelligence and actions capabilities in important aspects
- Design of virtual reality worlds
- Global warning systems against natural disasters and terrorists attacks
- Information systems to make medicine knowledge global and treatment personalised.
- Design of advanced human-computer interfaces.
- Insights, methods and tools for management, analysis, processing and visualisation of huge (up to petabytes and exaflops) data sets and data streams (up to trillions of records).

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS II. - briefly

- To design cyberarmies and cyberwarfare to protect countries information processing spaces (espacially the overall power, water, fuel, communication and transposition systems) against cyberattacks and cyberespionage.
- To develop simulators of human bodies organs, especially of brain.
- To fully develop potential of 3D printing.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SECURITY I

Perhaps the most complex, difficult and of huge immediate importance for the whole society is the challenge to make network information processing and information processing systems secure, in a broad sense.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SECURITY II

The goal of computer and information processing systems security is, in general, to protect integrity and confidentiality of data in storage, during processing and transmissions as well as information processing systems, processes and services from disclosers, tampering, damage or collapse by unauthorized parties and activities (by hackers or malicious programs) or by unplanned events.

Problems, the security challenge requires to deal with, are VERY complex. Negative consequences of breaking security can be Huge. It is therefore very unpleasant, and makes the challenge even greater, that in spite of a large effort in this area for years, and many local successes, the overall situation can hardly be seen as much improved.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SECURITY III

The security challenge is so formidable mainly due to the following five reasons:

(1) Society increasingly depends on reliable functioning of huge software and communication systems (for example those controlling major transportation systems for people, goods, energy, water, munition carriers, information, emails as well as in defence, finances, and so on). Their collapses due to "cyberattacks" could have huge consequences;

(2) Attackers are in principle capable (due to their larger motivation) to make a faster use of the progress in sciences and technologies than are able to do so those developing to-be-secure systems;

(3) To achieve sufficient security is so difficult also because strategies and methodologies to achieve information processing systems security are much different from other computer systems design technologies.

Moreover, unless security is taken care already in the design process, through so-called built-in security, especially into programming languages and operating systems, what is very costly and cumbersome, it is extremely difficult, almost impossible, to enhance security after the design is finished. To achieve computer security very special hardware and software tools as well as the system administration policies have to be used;

CONTINUATION - II.

(4) One needs to achieve multilevel security across multiple networks and domains with a variety of distributed information sources and targets and web applications and to have in such a complex and ever evolving environment well working tools for automatic monitoring and managing security threads;

(5) It is very hard to make users to cooperate and to behave in sufficiently security-concerned ways, in spite of the fact that trustworthiness, confidentiality, privacy and even anonymity of information is clearly of large importance.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SECURITY IV

There is nowadays a whole variety of ways security of information processing systems can be broken and also ways how "cybercrimes" can be carried out.

Viruses, worms, Trojan horses and "denial of services" as well as other malware and spyware, are perhaps the most known ones, but they represent only a small portion of the dangerous systems that have been already identified.

Security of huge software systems and communication networks should be seen as a very global problem of such systems and networks and to solve this problem it is not sufficient to ensure security of its basic components (processes/protocols) related to security problems of particular data and users.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SECURITY V

There is nowadays a lot of sophisticated techniques to ensure integrity and confidentiality of data in storage and during communications as well as identity, digital signatures, privacy or anonymity of users at simple and isolated communication schemes.

However, all these problems get a completely different dimension in case of communication in huge (global) networks where it is hard to check or even know all channels information has to go through.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SECURITY VI

Quite promising, but still not sufficiently explored are recent attempts to use quantum phenomena (quantum non-locality), laws (Heisenberg uncertainty) and limitations (no-cloning theorem), to create a new level of security - so-called unconditional security - for certain security tasks.

Concerning security, we won several battles, but we are loosing the war.

A. Shamir, one of the inventors of RSA cryptosystem and one of the leading cryptographers.

MALWARE -MALICIOUS SOFTWARE

- It is claimed that each year about 280 millions of new pieces of malware appear.
- Malware is growing so capable that it can be considered as exhibiting some intelligence.
- Expertize in malware has become commoditized - you can even hire easily hacking services and products.
- Most of malware is created by software that writes softwarw.
- There are many types of malware - all of them have as a goal to exploit computers without the ownerś contents.
- Malware can also enslave computers themselves as a part of a botnet - robot network.

BOTNETS

- A botnet is often comprised of a million of computers - that have been infected by a malware.
- n 20111 botnet victims increaased more than 650%.
- Using botnets or simple malware to steal from computers grew from multimillion dollars in 2007 to one-trillion dollars industry by 2010.
- Cybercrime has become a more lucrative business than the illegal drug trade.

CYBERATTACKS

- Cyberattacks are of enormous danger and hard to defend from.
- Internet can be seen as a new domain of warfare - along with land, see and sky.
- One point is that the attacker has to succeeed once in a thousand attacks,the defender has to succeed evry time - it is a mismatch.
- Another point is that de luxe antiwirus software is between 500 and 1000 megabytes in size but the average piece of malware has often only 150 lines.
- From 2007 to 2009 an average 47,000 cyberattacks a year were against Department of Deffence, State, Homeland security and Commerece.
- China is seen as responsible for 30% of all targeted attacks against US facilities.

STUXNET

- Perhaps the most famous are outcomes of the malware "suxnet", developed by US-Israel effort.
- It is claimed that stuxnet crippled during ten months between 1,000 and 2,000 centrifuges in natanz, Iran and by that allegedly set back Irańs nuclear weapons development rogram by two years.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - SOFTWARE DESIGN I

The second grand challenge is to develop methods and tools to specify, design, analyse, verify, maintain and make reliable unprecedentedly large and complex software and hardware systems, often ever evolving. Systems the state space of which is often far larger than the state space of any of the systems in the universe.

This challenge inspires also much scientific Informatics. Formal systems are perhaps the main basis for the development of powerful and reliable methodologies, tools, systems and finally also skills. Evidence amounts that security issues have to be embedded into all stages of the design and maintenance of huge systems.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - MORE MOORE - I.

Another grand challenge is to keep prolonging much validity of the Moore law for performance of information storing, processing, imaging and communication technologies as well as to create technologies to transfer and to reproduce sounds, smell and other sensual information (needed much to create real virtual reality).

New materials to replace silicon, to achieve low-energy consumption, high fidelity and cost-effectiveness are by that key issues.

GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - MORE MOORE - II.

Massive parallelism and fragile micro- and nano-world objects and effects, down to the quantum objects and effects, seem to be main current way to increase information storage and processing power.

- In 2008, scientists from the University of Manchester announced a transistor 1 atom thick and 10 atoms across;
- In December 2009 a working transistor was announced that was made of a single (benzene) molecule (attached to gold contacts) by a team from Yale University and from South Korea;
- In January 2010 Intel announced 25nm NAND flash.

CASE STUDY: DNA and MOLECULAR COMPUTING

- DNA computing has been developed already for quite a while as a form of computing that uses DNA, biochemistry and molecular biology to do computation.
- For example, in 2002 a programmable molecular computer composed of enzymes and DNA molecules was announced (by scientists from Weizman Institute of Science in Rehovot);
- In 2004 a DNA computer was announced by, E. Shapiro et al., that was coupled with an input and output module which would theoretically be capable of diagnosing cancerous activity within a cell, and releasing an anticancer drug upon diagnosis;
- In 2009 bio-computing systems were coupled, by scientists from Clarkson University, with standard silicon based chips for the first time.
- In 2009 Strassen's matrix multiplication algorithm has been implemented on a DNA computer.
- In 2011 researchers in Caltex designed a circuit made from 130 DNA strands to calculate square roots of numbers up to 15.
- In 2013 In Weizman institute they were able to store a JPEG photo, a set of Shakespearen sonets and an audio file of Martin luther's speech in DNA-digital data storage.

GRAND CHALLENGE: ATOMIC and MOLECULAR SCALE ICT DEVICES

Another big challenge is to explore the potential of a single atom, a molecule or a small assembles thereof, as elementary functional resources for future ICT systems.

The key issues to take care about are the existence of robust fabrication processes, control, sensing and picometer interconnection precisions, etc.

FURTHER GRAND CHALLENGES of TECHNOLOGICAL INFORMATICS - I.

The fourth grand challenge is to design, analyse and maintain a global, ever evolving and geographically distributed computer (network).
A global computer capable to process, in an efficient, intelligent and secure (and privacy preserving) way, huge amounts or streams of data and tasks, as well as to store most (all) of information and knowledge all fields of science, technology, learning, scholarship, art, medicine and so on produce, and in such a way that all can be efficiently retrieved and used if needed.

CONTINUATION I.

The global/total computer challenge amounts, in a limit, to a creation of a heterogeneous, distributed and ever evolving huge computer network of computers accumulating all available knowledge and information producing and processing resources and tools.

Design of such a global computer would result in a new synthesis of different areas of science, technologies, environmental and health care and so on with informatics products as a gluing and interacting substance.

Currently, as a way to deal with this challenge, are notable efforts to design a "New generation internet", an "Internet of people", "Internet of things" (computers, sensors, home devices, medical equipment, smart devices, etc.) and "Internet of (digital) content" as platforms for "cloud computing".

Emphasis are on built-in privacy, security, as well as on efforts to make integration of satellite and terrestrial communication technologies.

Internet and cloud computing technologies will radically change how people and businesses use technology and individuals live their lives.

INTEGRATION of HETEROGENEOUS TECHNOLOGIES

The goal is an integration of key enabling ICT technologies for components and systems across multiple research fields (nano-technology, organic electronics, micro-nano-bio systems, bio-photonics) materials (organic and inorganic) and functions (sensing, actuating, communicating, processing, energy harvesting).

Emphasis are to be given to support the semiconductor heterogeneous integration (hardware, softwar, photonics etc.).

EXASCALE COMPUTING SYSTEMS

The goal is to develope computing platforms, technologies and applications for exascale computing.

The poin is to address such challenges as:

- Efficient management of extreme parallelism with millions of cores.
- Development of system libraries in the area of I/O
- Middleware, programming models and modeling architectures to address the increasing heterogeneity of systems;
- Modularity, parallelisation and scalability of applications
- Data-driven/data-intensive computations

The design of systems capable of activities that used to be in the domain of living beings, especially concerning intellectual capabilities, and systems imitating behaviour of living beings is another big challenge of technological Informatics in cooperation with scientific Informatics and several other areas of technology.

Of a special interest is the design of robots, namely of robots capable to replace people in situations people can hardly operate in or their precision is not sufficient - in space and deep-sea explorations or activities, surgeries and so on.

GRAND CHALLENGE: COGNITIVE SYSTEMS and ROBOTS II.

A lot of progress has been already done in designing industrial robots to be used in manufacturing, assembly, packing, transport, weaponry and so on.

In a quite advance state is the design of artificial hands, legs, walking robots and humanoids robots.

Advances in the vision and simulation of other senses are of the crucial importance for that.

Unmanned fighting and surveillance air-crafts are perhaps highlights so far in this direction.

GRAND CHALLENGE: BIO-INSPIRED INFORMATION PROCESSING

Another grand challenge is to design information-processing artifacts inspired by those the nature has developed for information storing and processing.

Cells- and brain-inspired information processing are some of the main challenges.

Developments in bio-chips, bio-sensors and in-silicon biology are steps in this direction.

Big HBS (Human Brain Simulation) project a part of which is a new brain activities computer architecture is a significant step in such a direction.

NANOBOTS as a GRAND CHALLENGE

- Nanobots (or nanorobots) are small robots that can travel inside the bloodstream. This notion is not as futuristic as it may sound - many such micro-scale devises are already working in animals.
- Their main envisioned applications are: to facilitate brain reverse engineering by "sensoring" inside the brain; to perform a variety of diagnostic and therapeutic functions in human bodies.
- A. Freitas has designed: robotic replacements for human blood cell that perform 10^5 times more effectively that their biological counterparts; DNA-repair robot capable to correct DNA transcription errors and implement needed DNA changes.
- An important fact is that medical nanobots will not require such extensive overhead biological cells need to maintain metabolic processes such as digestion and respiration.
- Nanobots are expected to communicate among themselves and with :mainframes" and that they can be, using wireless communication, reprogrammed.
- A big problem concerning nanobots is that for many tasks an enormous number of them would be needed and so problem of their production and self-reproduction is very nontrivial.

GRAND CAHLLENGES: 3D PRINTING

- 3D printing is a process of creating 3D solid objects objects of virtuallyany shape from a digital model by an additive process.
- 3D printing is achieved by an additive process, where successive layers of moleculs are laid down in different shapes.
- A 3D printer can be seen as a type of industrial robot capable of carying out an additive process under computer control.
- The first 3D printer was designed in 1984.In 2012 market for 3D printers and services was worth 2.2 Billions of dollars, up 29% from 2011.
- 3D technology is used for prototyping and distributed manufacturing. Applications are: idustrial design, automotive and aerospace industries, dental and medical industries, biotechnology (human tissue replacement) fashion, footwear, jewelry, eyewear, food.

GRAND CHALLENGE: VIRTUAL REALITY SYSTEMS - I.

Design of ever improving virtual reality systems, especially virtual worlds, is another grand challenge of Informatics that can have enormous impact on the standards and style of working in many fields, including many sciences and technology fields, as well as on the way people live, develop and entertain themselves.

Virtual realities can be also seen as systems that create a sufficiently good, for a given purpose, illusion/impression of being either in the current or in one of the past or potential future real worlds or in an imaginary world. The illusion should be good enough, from the point of view of our senses, and impacts of "being" in these worlds on human brain and bodies should be (almost) perfect -

VIRTUAL REALITY SYSTEMS - II.

The term virtual reality/environment/world refers to computer-simulations of places and activities in the real world or in imaginary/fantasy worlds.

The first basic problem for the design of such systems is to simulate basic sensory experiences with high fidelity and cost-effectiveness. Quite advanced, and believed to come to a very satisfactory state soon, are simulations of the sight and sound (even 3D) experiences. On the experimental level are simulations of the smell experience and cost-effectiveness seems to be the main issue by that.

To meet this challenge requires a significant progress in several other areas of scientific and engineering Informatics.

Significant advances have also been in the simulation of the touch experience. For other senses simulations seem to need to manipulate brain directly what is currently on the initial experimental level.

The second basic problem is to simulate realistically advanced sensory experiences, especially to handle their changes, of the potential inhabitants of virtual reality, so-called avatars, as they move, handle objects and interact with the environment and other inhabitants. This includes a simulation of locomotion, balance senses, gravity, feelings, facial expressions, gestures and so on.

GRAND CHALLENGE: VIRTUAL REALITY SYSTEMS - IV.

Virtual worlds are virtual reality systems in which users can interact with the environment, with other users and other inhabitants, can use and create objects and perform various activities (social interactions, business, shopping, financial and so on) and socialize. One can then talk also about virtual economy, real-estate business, properties and their values, and also about advertisements for real worlds in virtual worlds.

Virtual worlds are fast growing in importance and impacts. There have been estimates that the number of people using virtual worlds has been increasing much every month. It was estimated, for example, that more than 600 millions of people used, in 2010, a virtual world and that their uses will be soon so widespread as are that of internet.

GRAND CHALLENGE: VIRTUAL REALITY SYSTEMS - V.

Virtual reality systems currently available are already successfully used in various design and training activities because they are faster, cheaper and allow easily to perform various tests and actions.

Museums and galleries as parts of virtual realities are quite clearly within the reach of foreseeable technology as well as visits of various interesting places of nature (as caves) or archaeological and our heritage places. Potential uses of the virtual reality systems for training and education (for example of drivers, pilots, surgeons seems to be great.

Possibility to switch to a virtaual reality and to live for a while in a different parts of the world or in different era can bring fascinating personal experiences, enhance people's internal life to new heights and bring also into a new dimension variety of behavioral and social sciences.

There are already no doubts that design of virtaul worlds is one way informatics should go. Less clear is where are limits it can go and limitations for being useful to do that.

GRAND CHALLENGE: DESIGN of GLOBAL WARNING SYSTEMS

This is another big challenge of engineering Informatics that requires a broad cooperation with other areas of science and technology.

The task is to crate huge networks of sensors and on the basis of data obtained from them to simulate model of the environment and to predict a natural disaster.

Similar, though much more sophisticated, systems are needed to detect potential terrorist attacks.

GRAND CHALLENGE: E-LEARNING

Another grand challenge is to develop Informatics based strategies and tools for personalized (e)learning that would be aimed to increase learning outcomes using systems tailored to specific learning capabilities and motivations of individuals.

The goal is to learn more effectively, in convenient time and way, and to support acquisition of new skills.

GRAND CHALLENGE: DESIGN of CREATIVITY ENHANCING TOOLS

Creativity start to be seen as one of the essential 21^{st} century skills in professional contexts.

On theoretical level the task is to develop formal understanding/theory of creativity and also ways to judge/measure products of creative activities of humans, computers a and hybrid, humans-computer systems, that could be judged as original and/or surprising.

The challenge is to provide better (and interactive) tools, capabilities and insights for those working in the "culture and creative industries", to enhance the creativity of people in these industries.

GRAND CHALLENGE: DESIGN of CREATIVITY ENHANCING TOOLS - I.

The goal is to design creative experience tools that can make use of all our senses and allow for richer, more collaborative and interactive experiences: real time simulation and visualisation, augmented reality, 3D animation, visual computing, games engines and immerse experiences.

Creative and cultural industries (such as advertising, architecture, arts, crafts, design, fashion, films, music, publishing, video games, Tv and radio etc.) represent 4.5% of total European GDP and account for 3.8% of the workforce.

GRAND CHALLENGE: IMPROVING HEALTH CARE

Another grand challenge of technological informatics or medical informatics is to create a variety of information processing systems to improve health care by making it global and to make also medical treatments more personalised and by that more efficient.

One of subchallenges is to develop ICT technologies supporting multiscale modelling and simulation of of human organs, systems and bodies, aggregating information from multiple biological levels - to create a personalised digital patient.

The model can be then used for in-silico clinical trials - for prediction of impacts of suggested treatments and drugs and to predict the overall evolution of patient health.

GRAND CHALLENGE: ADVANCED INTERFACES

Profound changes are needed to transform how consumer and business interface with ICT. In particular, development

- Touch screens
- 3D displays
- Augmented reality
- Multisensory interfaces
- Reliable multilingual speech recognition

Informatics

Science versus technology

BASIC VIEWS

Informatics as a science concentrates to a large extent on gathering knowledge. Curiosity and search for knowledge for its own sake should be its main driving forces.

Informatics as an engineering discipline has as its main concern demonstrable utility. Improvements of performance and reliability, as well as economical success, should be some of its main driving forces.

One can also say that the goal of science used to be seen as the quest for knowledge; the goal of engineering used to be seen as the quest for skills.

Informatics as a methodology and tools blurs to a large extent this distinction between the goals of scientific and engineering Informatics.

SCIENTIFIC versus ENGINEERING INFORMATICS - I.

- Distinctions between scientific and engineering Informatics are in many aspects blurry.
- Engineering Informatics is much helping scientific informatics in many ways to deal with its main challenges and attempts to explore information processing worlds and our physical and biological nature.
- Design of various models and simulations as well as virtual worlds in one of the ways to do that.
- On the other side, engineering informatics has to tackle specification, design, analysis and verification problems of such a dimension that without paradigms, insights, methods and tools they cannot be handled.
- Scientific and engineering informatics are therefore, and should be developed as, partners in both quest for dealing with most fundamental questions and most difficult design challenges.

SCIENTIFIC versus TECHNOLOGICAL INFORMATICS - II.

Our views of (natural) sciences and their (achievable) challenges have always been much shaped by available instruments: telescopes, microscopes, accelerators and so on. Telescopes and microscopes have changed astronomy, cosmology, biology, chemistry and physics - they increased much information gathering power of our eyes. High energy accelerators allow us to reach bottom of matter.

The possibility to turn the enormous power of computers, via sophisticated algorithms and carefully designed software, into new powerful instruments has much increased frequency of the design of new powerful instruments and by that the development of science and technology, medicine and so on.

The history of mankind teaches us that no matter how radically new a technology has been, it could have an immense impact on science, technology and society at large, only when a very new way of thinking and seeing the world had already been emerging for quite a while, in science and society, that could make full use of this technology.

The history of mankind also demonstrates that the main long run contribution of such a technology has always been to help to develop much further this new way of seeing, understanding and managing the world, and to help to make this new view of the world more coherent and more powerful.

SCIENTIFIC versus TECHNOLOGICAL INFORMATICS - IV.

Current science is often seen as being engineering driven and current engineering as being science driven.

The key fact behind is that Informatics paradigms, methods and tools play such a key role in both, in science and engineering.

They allow to pursue the quest for knowledge in such a way that engineering outcomes are a natural consequence of it.

On the other hand, current top engineering depends much on the scientific outcomes transformed mostly into the informatics driven/supported products.

HISTORY of TECHNOLOGICAL INFORMATICS

- The history of informatics, as of an area of technology and science, should be seen as being very old - as perhaps the oldest of technologies.
- In order to see properly the history of informatics as a science it is of large importance to realise that the "twin science" to informatics is not only mathematics but all "natural sciences".
- In order to see properly the history of informatics as an engineering discipline it is of large importance to realise that "twin technology" to informatics is not only electrical engineering, but all engineering.
- History of mathematics should be seen as a (very important) part of the history of informatics.
- A very crucial part of the history of biological systems will also be part of the history of informatics.
- Concerning history of information processing devices, created by nature, we are nowadays actually only in the very beginning of its understanding.
- Similarly, we are still in the very beginnings of understanding of the development of the universe and life as of (quantum?) information processing systems.

APPLIED INFORMATICS

APPLIED INFORMATICS - GOALS and GRAND CHALLENGES

Main goals and grand challenges of applied informatics are motivated by the following facts

1. We are coming to the peta(exa)-world with computers of peta(exa)flops performance and petabytes memories.
2. In 20-30 year we can expect to have for 1000 $ computers with information processing power larger than of all human brains.
3. We are coming fast to the world with ever increasing merge of bio- and non-bio- intelligence.
4. Informatics methods and tools helped already much to assemble human genome and database of genomes is expected to have big value in our understanding of life and evolution, in new drugs developments etc.

APPLICATIONS of INFORMATICS in ACADEMIC DOMAINS - I.

- The main application of informatics in the academic domain consists of an infiltration of its concepts, paradigms, methods and tools to other academic disciplines.
- This allows not only to solve problems that were out of considerations before so powerful information precessing and communication tools were available.
- The most important is that it allows to ask new questions that could not be asked before and especially questions the answer to which may lead to unforeseen insights and can therefore revolutionize thinking in a field.

- For example, it is quite obvious that there are questions in many areas of science that cannot be answered unless huge amounts of data are collected and processed.
- For example, in astronomy, earth sciences, particle physics, genetics and so on.
- Less obvious is that there are are types of informatics-driven questions that can have other enormous and fundamental impacts.
- For example, questions about information processing power of quantum phenomena revealed an enormous power of entanglement and non-locality. That is of the features that used to be seen as strange, useless and even contra-intuitive.

WAYS INFORMATICS FACILITATES its APPLICATIONS I

- Informatics makes fast many very successful steps, in cooperation with other areas of science and technology, to achieve its goal that information processing "energy" is available easily, anytime, everywhere, to everyone and from anyplace.
- Design of global sensors-, surveillance- , as well as computers networks, through the development of grid computing, peer-to-peer computing, wireless- and mobile- as well as cloud computing, ...; development of better and better web services (as the semantic web promises) and search engines, are some of the main current steps towards that goal.

WAYS INFORMATICS FACILITATES its APPLICATIONS II

- In all these areas goals are so ambitious that one starts to talk about global computing on one side and on "dust and clay computing" and molecular computers to explore human cells on the other side.
- Informatics makes fast and successful steps, in cooperation with other areas of science and technology, to achieve that data mining and information/knowledge retrieval devices, as well as information processing and providing systems, penetrate "everything and everyone" - that information processing is so ubiquitous that it is thoroughly integrated into many objects and activities even of our everyday personal and domestic life.

WAYS INFORMATICS FACILITATES its APPLICATIONS III

- Design of embedded systems, developments in so-called ubiquitous/pervasive computing, as well as in the so-called ambient intelligence, are some of the main current developments towards that goal.
- One of the most ambitious sub-goals is to embed nano-scale monitoring, data retrieving and drugs delivering systems (to proper places) into human bodies.
- A perhaps bit less ambitious goal is the design of domestic ubiquitous computing and robotic environments.

WAYS INFORMATICS FACILITATES its APPLICATIONS IV

- Nano-scale miniaturization and low-energy consumption are some of the main issues in this context. Embodiment, environment/context-awareness, adaptivness and anticipation are some of the main concerns.
- All that goes so far that one starts to see large parts of medicine as being soon developed as applied robotics and to consider entertainment industry and show business as being soon Informatics, especially robotics, animation and virtual worlds driven. It seems to be also only a question of time when this will be the case also for sport industries.

WAYS INFORMATICS FACILITATES its APPLICATIONS V

- Informatics takes special care for improving human-computer, computer-computer, computer-human and human-human communication and interaction.
- Developments in the area of wireless networks, mobile computing and communication on one-side, as well as a concentration on the development of the user/human-centric information processing devices and voice- as well as brain-driven computing, are some of the main developments in that directions.
- Under explorations are also human-computer interfaces based on gestures, mimics, body postures, emotions and so on.

WAYS INFORMATICS FACILITATES its APPLICATIONS VI

- Informatics starts to take special care that its methodology will be massively used and actually will penetrate human reasoning to such an extent that "information processing dissolves into behaviour" and "behaviour will be driven to a large extent by information processing paradigms, tools and outcomes".
- Attempts to teach so called "computational thinking", and ways to incorporate it into all spheres of the education process, are an example of activities along these lines.
- Attempts to push education concerning *fluency with information processing technology* into all forms of education are another step in this direction.

- Informatics takes special care to develop theories, methods and tools to make better use of the so-far accumulated information and knowledge in learning, scholarship, science, technology and so on and also and products in sciences, technologies, medicine, archeology, music, art and so on.
- This is done, on one side, by developing techniques of (also semantics driven) searching through enormous amounts of texts, images and also through more dimensional data.
- A search for similarities play by that the key role and represents a big challenge of the field.

- Development of the corresponding theories and methods can have very broad applications and especially medicine and life sciences could profit enormously out of it.
- Archeology, history and music are other areas that could be much changed by such techniques.
- On the other side, this leads to the design of digital encyclopedias, (global) digital libraries, galleries, museums, archives and so on.
- The main outcome of that could be an enormous enhancement of personalized learning and also of personalized entertainment.

CURRENT GRAND CHALLENGES of APPLIED INFORMATICS

- To informatize all production processes and at the same time to put care for protection of intellectual rights at another level.
- To create global and intelligent information and knowledge precessing systems for health care.
- To create global and intelligent information and knowledge processing systems for environment care.
- To create complex information and knowledge processing systems to bring governance on local and state levels to another level of efficiency, transparency and democracy.

CURRENT GRAND CHALLENGES of APPLIED INFORMATICS - I.

- To create global and intelligent information processing systems for making our cultural heritage available from anywhere to anybody.
- To digitize all available knowledge and information in a proper structural way and to have it trustworthy and retrievable. (Trustworthiness of the available digital networks information is a huge problem due to the decentralisation of the process of its creation.)

CURRENT GRAND CHALLENGES of APPLIED INFORMATICS - II.

- Digitalization of all information and knowledge and its storing should be done in such a way that information and knowledge would be accessible by anyone from anywhere anytime and almost immediately and, in addition it can be quite "easily" updated.

CURRENT GRAND CHALLENGES of APPLIED INFORMATICS - III.

- To explore how informatics-based tools and methodologies will not only change human and societal potential but also the overall culture and the inner worlds of individuals.

CURRENT GRAND CHALLENGES of APPLIED INFORMATICS - IV.

- To deal with formidable social and legal problems related to the privacy, intellectual property rights, security and so on that global networking, commerce, financing and so on are bringing.
- A big challenge is to extend, in a scalable way, the internet to a global system handling several orders of magnitude more users, more information, more (as well as more complex) services and more diversified uses, and all that in a reliable, secure and fast way preserving privacy and intellectual rights.
- To find out how to make an effective use of the enormously fast growing wealth of data, information

CASE STUDT - OPENESS PROBLEM

- Enormous problem is how to store enormous amounts of data scientific instruments and processes produce in such a way that they remain accessible also to future generations.
- Only LHC produces 25 petabytes of "raw" data per year. This is only a thousandth of the real raw data produced by detectors that are already filtered to remove "uninteresting data". The rate of real data is cc. 300 GB/s. The obvious fact is that a huge amount of gathered data is definitively lost.
- Having access to the knowledge and wisdom of previous generations has been vital for the success of mankind and in non-negligible extend this applies also to the raw scientific data. This poses a lot of potential barricades that has to be overcame - permanent storage and preservation of data and data accessibility.
- The permanent and open access to the knowledge base we have is a challenge for the informatics and will become a big challenge in future with growing amounts of data and users.
- Having the development as well as results of science preserved and available is a crucial point for mankind's advancement in science and technologies.
- It is a big challenge of informatics to provide better and better tools, mechanisms and in general environments for such open source and collaborative efforts.

APPENDIX

IMPORTANCE of MACHINES for UNDERSTANDING of NATURE

- Many of the most general and powerful discoveries of science have arisen, not through the study of phenomena as they occur in nature, but, rather, through the study of phenomena in man-made machines, in products of technology.
- This is because phenomena in man's machines are simplified and ordered in comparison to those occurring naturally, and it is this simplified phenomena that one can understand more easily.

HUMAN GENOME PROJECT (HGP)

This was one of the largest and most important of the recent research projects in which methods and tools of informatics played an important role.

HISTORY of HGP

- The idea to create such a project started to be discussed in 1984.
- The project started in 1988 with participation of 20 leading institutions from 6 countries and was scheduled for 15 years.
- The goal was to finish complete human genome sequence by th end of 2013.
- A rough draft of humane genome (90% with one error per 1,000 base pairs) was finished in June 2000; final version, on April 2003, covered 99% with 1 error for 10, 000 base pairs.
- Project cost from US taxpayers was 2.7 billions of dollars - a bit less than planned (3 billions)

- A genome is an organism's complete set of DNA.
- DNA molecules are made of two twisting , paired strands.
- Each strand is made of four chemical units, called nucleotide bases and denoted A, T, G, C.
- The human genome contains approximately 3 billions of such pairs, which reside in 23 pairs of chromosomes within the nucleus of our cells.
- Each chromosome contains hundreds to thousands of genes, which carry instructions for making proteins.
- Genome sequencing means determining the exact order of the base pairs in a sigment of DNA.

- Human chromosomes range in size from about 50 to 300 millions base pairs.
- The primary method used by the HGP to produce the finished version of the human genetic code is BAC-based sequencing - the acronym for "bacterial artificial chromosome".
- Human DNA is fragmented into large, but still manageable pieces and such fragments are cloned in bacteria, which store and replicate the human DNA so it can be prepared in quantities large enough for sequencing.

BIOINFORMATICS and COMPUTATIONAL BIOLOGY OFFICIAL GOALS of HGP

- Improve content and utility of databases.
- Develop better tools for data generation, capture and annotation;
- Develop and improve tools and databases for comprehensive functional studies.
- Develop and improve tools for representing and analyzing sequence similarity and variation.
- Create mechanisms to support effective approaches for producing robust, portable software that can be widely shared.

IMPACTS

- The GHP has already fueled the discovery of more than 1800 disease genes.
- Due to HGP outcomes today's researchers can find a gene suspected of causing an inherited disease in number of days.
- There are now more than 2000 genetic tests for human conditions. They enable patients to learn their genetic risks for diseases and also help to diagnose diseases.
- To summarize, we can say that informatics methods and tools helped to assemble human genome and the database of genomes is expected to have enormous value in our understanding of life and evolution, in health-care and in the development of new drugs.

NEXT STEPS - I.

- New project "The Cancer Genome Atlas" aims to identify all the genetic abnormalities seen in 50 major types of cancer.
- 100K Genome project (2012-2017). Goal is to sequence genome of 100,000 infectious microorganisms. Application: to speedup the diagnosis of foodborne illnesses. This is a public-private collaborative project. Completed gene sequences will be stored in a public database and are expected to be used to develop new methods of controling disease-causing bacteria in the food chain.

NEXT STEPS - II.

- Progress in genome sequencing can be summarized as follows:
  - In 2003 first genome was sequenced in 15 years and at a cost of more than 3 billions of dollars.
  - In 2008 the genome of James Watson, DNA discovery man, was sequenced in 4 months at the price of 1 million of dolars.
  - In 2012 a possibility was annonced to make a genome sequencing in 1 day at the price of one thousand of dollars.