Part XXIX

Future of Informatics - Chapter 8

Chapter 8: GNR revolution

as paving the way to Epoch 5
and creating a basis for the beginning of Singularity

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WISDOMS

- There is nothing in biology found yet that indicates the inevitability of death.

  Richard Feynman

- It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.

  James Watson, Francis Crick, 1953

- After three billions years of evolution, we have before us the instruction set that carriers each of us from the one-cell egg through adulthood to the grave.

  R. Waterston

- First we build the tools, then they build us.

  Marshall McLuhan

- A year spent with AI is enough to make me to believe in God.

Alan Perlis

REVOLUTIONS PAVING THE WAY to SINGULARITY

Three revolutions, that have initiated already quite a while ago, are expected to change our lives enormously and pave the way for Singularity. Their exponential evolution is expected to dominate the first half of 21st century.

Genetics: By understanding information processes underlying life, based on DNA, we expect to start to learn to reprogram our biology and to simulate life in much more efficient and reliable substrates. We expect also to achieve dramatic improvements of human potential and to achieve drammatical life extension.

Nanotechnology: Miniaturization, that nanotechnology is to offer, should allow to redesign and rebuild - molecule by molecule - our bodies and brains and the world we interact with, going far beyond limitations of biology. In addition, it is to allow to design nanobots of such importance for non-invasive scanning of human bodies, for medical treatments as well for preventing aging.

Robotics: Strong AI (Artificial intelligence) is expected to produce robots with physical and intelligence power far exceeding human potential and capabilities. In order to do that the outcomes of genetic and nanotechnology revolutions are to play key role. Outcomes of robotics, or strong AI, will be behind the most significant transformations of society.

While all three revolutions will allow to solve many big problems of the past, they are also expected to bring new perils/dangers, hard to imagine now fully. Dealing with them can

GENETICS

as intersection of biology and informatics

and

as basis for biotechnology - a bridge to nanotechnology

- The laws of genetics apply even you refuse to learn them.

  Allison Plowden

- Human beings are ultimately nothing but carriers - passageways - for genes. They ride us into the ground like racehorses from generation to generation. Genes do not think about what constitutes good or evil. They don't care whether we are happy or unhappy. We are just means to an end for them. The only thing they think about is what is the most efficient for them.

  Haruki Murakami

FROM MENDEL

to

GENE SEQUENCING

WHAT is GENETICS

- Genetics is in general the science of genes, heredity, and variations in living organisms.
- Genetics deals with the molecular structure and functions of genes, with genes behavior in the context of a cell or an organism, with patterns of inheritance from parents to offsprings, with gene distribution, variations and changes in populations.
- Since genes are universal to living organisms, genetics can be applied to the study of all living systems, from viruses, bacteria, plants, animals to humans.

HISTORY of CLASSICAL GENETICS

- Modern science of genetics began with the applied and theoretical work of the monk Gregor Mendel from Brno, who studied the nature of inheritance in plants.
- In 1865, in the paper "Versuche über Pflanzenhybriden", Mendel traced the inheritance patterns of certain traits in pea plants and described them mathematically.
- Mendel's work started to be known and appreciated only after 1890, after his death.
- The word genetics was coined in 1905 by William Bateson from England, a proponent of Mendel's work.

HISTORY of MOLECULAR GENETICS

- After the rediscovery of Mendel's work, scientists tried to determine which molecules in the cell are responsible for inheritance.
- In 1911, T. H. Munt came with the claim that genes are on chromosomes and in 1913 his student A. Sturtevant showed that genes are arranged linearly on the chromosomes.
- Chromosomes are composed of protein and DNA and it was only in 1944 when DNA was identified, and only in 1952 experimentally confirmed, as the molecule responsible for inheritance.
- The helical structure of DNA (i.e. shaped like corkscrew), was determined by James D. Watson and Francis Crick in 1953.
- Their double-helix model had two strands of DNA with nucleotides pointing inward, each matching a complementary nucleotide on the other strand, to form what looks like rungs of a twisted ladder.
- The structure also suggested a simple method for duplication: if strands are separated, new partner strands can be reconstructed for each based on the sequence of the old strand.

SEQUENCING GENETIC CODE

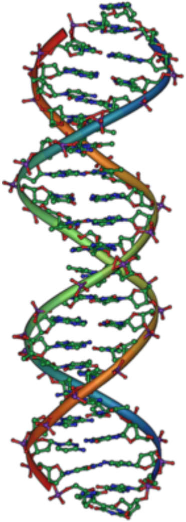
- After the development of molecular understanding of inheritance an explosion of research started.
- In 1977 a method was developed to read the nucleotide sequence of a DNA molecule.
- In 1983 K. B Mullis developed a quick way to isolate and amplify a specific section of a DNA from a mixture.
- That was the ground for establishment of Human Genome Project and sequencing a complete human genome in 2003.

GENOMICS

- The large amount of genome sequence data available has created the field genomics - research fields that uses computational tools to search for and analyse patterns in the full genomes of organisms.
- Genomics can also be considered as a subfield of bioinformatics, which uses computational approaches to analyze large sets of biological data.

STRUCTURE of DNA

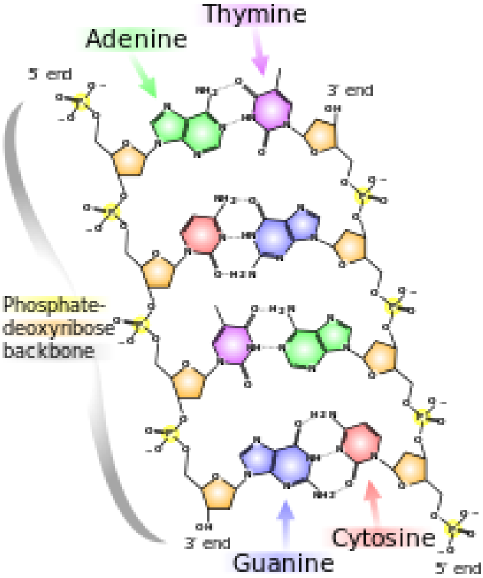
Each strand of DNA is a chain of nucleotides, matching each other in the center, to form what looks like rings on a twisted ladder.



STRUCTURE of DNA - I.

Each strand of DNA is a chain of nucleotides, matching each other in the center, to form what looks like rings on a twisted ladder.

MOLECULAR STRUCTURE of DNA



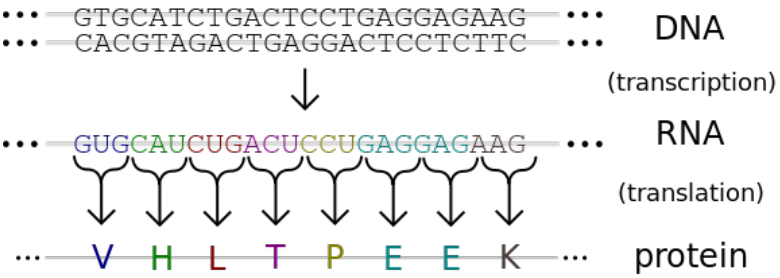
FROM GENES to GENETIC CODE

- Mendel observed that organisms inherit traits by way of discrete units of inheritance, which are now called genes.
- Genes correspond to regions within DNA. Each strand of DNA can act as a template for creating a new partner strand. This is a physical method for for making copies of genes that can be inherited.
- The sequence of nucleotides in a gene is translated by cells to produce a chain of amino acids, creating proteins - the order of amino acids in a protein corresponds to the order of nucleotides in the gene.
- This relationship between nucleotide sequence and amino acid sequence is known as genetic code.
- The amino acids in a protein determine how it folds into a 3D shape. This structure is responsible for the protein's function. Proteins carry out almost all functions needed for cells to live.
- A change to the DNA in a gene can change a protein's amino acids, changing its shape and function and this can have a dramatic effect in the cell and on the organism as the whole.

GENERATION of GENETIC CODE

- The process of producing protein from genes begins with the production of so called RNA molecule (a messenger RNA) with a sequence matching the gene's DNA sequence - a process called transcription.
- This messenger RNA molecule is then used to produce a corresponding amino acid sequence through a (coding) process called translation.
- During coding each group of three nucleotides in the sequence creates one of 20 possible amino-acids in a protein or an instruction to end the amino acids sequence.

PICTORIAL VIEW of GENETIC CODE GENERATION



POTENTIAL of DNA for COMPUTING

- DNA in each cell contains 3 to 5 millions of base pairs;
- It can be seen as 2m long and 2nm thick and with 750 MegaBytes; an elaborate packing makes them to fit into a cell only 1/2500 of an inch across
- In a human body we have 3 billions of cells, DNA as 5×10^9 km long and with 7.5 OctaBytes.
- Nature uses DNA to organize life in various ways, mainly using proteins.
- However, there is no reason not to assume that we can try to use DNA/RNA in different ways than nature and to build nano-devises including nano-computers.

DNA and MOLECULAR COMPUTING EXPERIMENTAL DEVELOPMENTS

- 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 the Weizmann 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 a diagnosis;
- In 2009, bio-computing systems were coupled, by scientists from Clarkson University, with standard silicon based chips for the first time.

FROM DNA to LIVING CREATURES

Behind all wonders of life, and also all misery of diseases, there are information processes run by surprisingly compact and simple programs executed by simple biological machines.

- The entire human genome has, after redundancies are removed, only 80-100 millions of bytes - not much more than average software program.
- The genome code is supported by a set of biochemical machines that translate linear sequences of DNA letters into strings of simple building blocks called amino acids.
- Amino acids are in turn folded, using special enzymes, into 3D proteins which make up all living creatures.
- Simulation of this process starts only now to be feasible because of the enormous complexity of all forces from all the atoms involved.
- Special molecules protect and guide the amino acid strands as they assume their 3D protein configurations.
- The amino acids are relatively simple, consisting of a carbon atom with its four bonds linked to: one hydrogen atom, one amino (-NH_2) group, one carboxylic acid and one hydrogen atom.
- The protein chains then control everything else.
- This machinery is essentially a self-replicating nanoscale replicator that builds elaborate hierarchy of structures and increasingly complex systems of living creatures.

CAN WE LIVE FOREVER?

CAN WE REALLY LIVE "FOREVER"? I. BASICS

Basic observations. Developments in genetics, biotechnology, nanotechnology and informatics provide reasons for seeing diseases, aging and death as calamities we should try and can fight. The following are main grounds for seeing such mega-challenge as

plausible.

- Discovery of the genome and capability to read it and modify it as well as expected consequent development of the genome engineering.
- Biotechnology paves an important way for nanotechnology and they, together with the progress in informatics, create a potential to control information processing processes in cells and to deal with cells' changes on cell levels as well as to clone living organs.
- In particular, we start to be able to reprogram our biochemistry because we start to have knowledge and tools to overcome our genetic heritage. At least in many (vast majority of) cases.

CAN WE REALLY LIVE "FOREVER"? I. TOOLS

- So called degenerative diseases - heart diseases, strokes, cancers, type-2 diabetes, liver and kidney diseases - account for about 90% of deaths. Our understanding of their principal reasons is rapidly growing and strategies as well as tools have been identified how to reverse and even prevent such processes.
- As discussed below, understanding and tools ar being dveloped to fight aging what can soon result with significant increase of the life expectancies.
- The ideas, at the moment at the level of science fiction, but that can hardly be seen as never possible, to clone and upload into computers human mind, could lead to a weak form "of living forever".

AGING - COMBATING KEY AGING PROCESSES - I.

De Grey identifies the following key aging processes.

- DNA mutations. Mutations to DNA in chromosomes in the nucleus result either in a defective cell, that can be quickly eliminated, or in a cell that does not function optimally and then affects orderly cellular reproduction, resulting in cancer. If we would be able to cure cancer, DNA mutation would be largely harmless.
- Toxic cells - they are cells that reach such a state that it would be better would they did not survive. Methods are being developed to target "suicide genes" to such cells and also methods are developed to tag such cells in a way that directs the immune system to destroy them.
- Mitochondrial mutations. This is the aging process due to the accumulations in thirteen genes in the mitochondria - the energy factories for the cell. These few genes are critical for the efficient functioning of our cells and undergo mutations at a higher rate than genes in nucleus. Methods have already been developed for transferring mitochondrial genes into the nucleus in cell structures.

AGING - COMBATING KEY AGING PROCESSES - II.

- Intracellular aggregates. Toxins are produced both inside and outside cells. Proteins have been identified that can destroy virtually any toxin.
- Extracellular aggregates.Undesirable cross-links of useful molecules are side effects of excess sugar. These cross-links interfere with normal functioning of proteins and are seen as key contributors to the aging process. An experimental drug, ALT-711, have already been developed that can dissolved these cross-links without damaging the original tissue.
- Cell loss and antrophy. Our bodies have the means to replace worn-out cells, but this ability is limited in some organs as we age, for example concerning cells in the heart. A primary combat strategy in this case is to deploy therapeutic cloning of our own cells as discussed below.

COMBATING AGING - STATE of the ART

- Progress in combating main sources of aging is moving rapidly in animal models and so one can expect its soon translation into human therapies.
- Another reason and clue to optimism is the discovery coming from the genome project that no more than a few hundred genes are involved in the aging process. By manipulating these genes, radical life extension has already been achieved in simpler animals.
- Another idea that seems to be very promising, and is currently explored, is to use biotechnology and nanotechnology to turn some biological cells into "computers" to make "enhanced intelligence" cells. (Once we will have the ability to program cells we can program them to perform new tasks.)
- The main new philosophy is to see not only diseases, but also aging and death as calamities that we have a chance, and should learn, to fight.
- Biotechnology, with the help of nanotechnology, keep providing means to change our genes, to replace or to build new organs and to make other steps to fight aging.
- The main new paradigm along these lines is to change information processing underlying biology.

CLONING TECHNOLOGIES

In spite of the fact that human cloning is currently not feasible, and also not desirable, especially for the ethical reasons, because perfect cloning is not yet feasible, some technologies for cloning of life products may be of importance soon for a variety of reasons.

- Cloning may offer the ability to directly reproduce an animal with a desired set of genetic traits.
- Cloning can be used to preserve endangered species and to restore extinct ones.
- Cloning can be used to create new tissues with patients' own DNA by converting one type of cells (say skin cellar) into another. (Liver cells have already been reprogrammed into pancreas cells.) Along these lines are prospects to replace ones organs and tissues with their "younger" replacements without surgery.
- Cloning can be used to deal with the World Hunger Problem by creating meat and other protein sources in factories without animals by cloning animal muscle tissue.

In spite of all current problems, some form of human cloning is likely to be feasible and also acceptable in future.

NANOTECHNOLOGY - THE INTERSECTION of PHYSICS and INFORMATICS

Nanotechnology - the intersection of physics and informatics

or

Nanotechnology - as the intersection of physics, genetics and informatics

WISDOMS

- There is plenty of room at the bottom.
  R.Feynman addressing American Physical Society, 1960
- Size does matter. Nano even more.

  Toba Betta
- The role of infinity small is infinitely large.

  Luis Pasteur
- I am not afraid to consider the final question as to whether, ultimately, in the great future, we can arrange the atoms the way we want; the very atoms, all the way down.

  Richard Feynman

WISDOMS - I.

- What the computer revolution did for manipulating data, the nanotechnology revolution will do for manipulating matter, juggling atoms like bits... This multidisciplinary synthesis opens the door to the new field of molecular manufacturing.

  Ralp Merkle

- Nanotechnology has given us the tools....to play with the ultimate toy box of nature - atoms and molecules. Everything is made of it.... The possibility to create new things appear limitless.

  Horst Störmer

WISDOMS - II.

- We humans will astonish ourselves... Atom by atom we will assemble small machines that can enter cell walls and make repairs. This month comes the extraordinary, but inevitable news that we synthesize life, and in the coming years we will not only synthesize it, but engineer it to specifications.

  J. Bezos, 2010, Amazon.com founder

- Nanotechnology will let us build computers that are incredibly powerful. We will have more power in the volume of a sugar cube than exists in the entire world today.

  Ralph Merkle

- The future lies in designing and selling computers that people don't realize are computers at all.

  Adam Osborne

- Nanoscale is more interesting than the atomic scale because the nanoscale is the first point we can assemble something - it is not until we start puting atoms together that we can make anything useful.

  Horst Stömer

NANOTECHNOLOGY - I.

- Nanotechnology is, in narrow sense, the manipulation of matter on an atomic and molecular scale.
- Nanotechnology is, in broader sense, manipulation of matter with at least one dimension from 1 to 100 nanometers.
- The lower limit is set by the size of atoms (hydrogen has the smallest atoms, which are approximately a quarter of a nm in diameter).

- Much of the fascination with nanotechnology steams from the fact that many materials when reduced to nanoscale show very different properties compared to what they exhibits on macroscale. For example, special surface/quantum phenomena - what enables unique and surprising applications.
- For example, gold, which is chemically inert at normal scales, can serve as a potential chemical catalyst at nanoscales. Substances that are insulators normally , meaning that they cannot carry electrical charge, become semiconductors when reduced to nanoscale.

NANOTECHNOLOGY - III.

- In micro and macro world you can't walk up to a wall and then immediately teleport to other side of it, but at nanoscale one can. This is called electron tunnelling.

HOW BIG IS NANO?

- One nanometer (nm) is one billionth, or 10^{-9}, of a meter - less than the wavelength of visible light.
- By comparison, typical carbon-carbon bond length, or spacing between these atoms in a molecule, are in the range 0.12-0.15 nm.
- Most of atoms are about 1nm in diameter.
- An atom's nucleus is about 0.00001 nm.
- DNA double-helix has diameter around 2nm.
- On the other hand, cellular life-forms, the bacteria of the genus Mycolasma, are around 200nm in length.
- Cells are nature nanomachines.

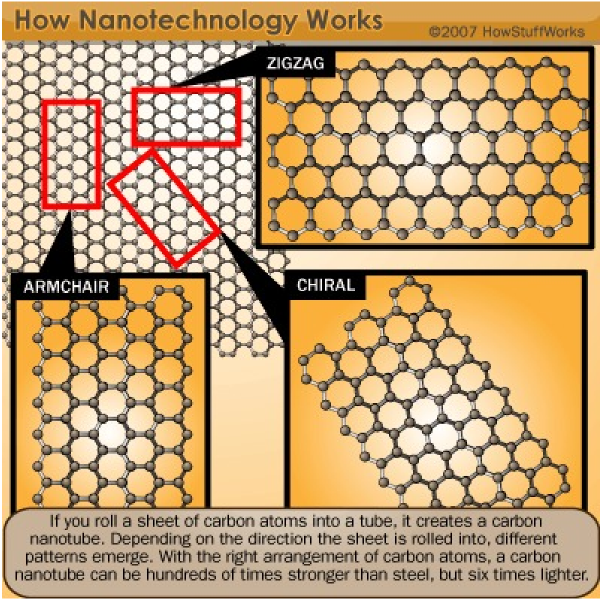
HOW TO SEE NANOOBJECTS

- Nanoobjects are so small that one cannot see them even with light microscope.
- Nanoscientists have to use tools like scanning tunneling microscopes or atomic force microscopes to observe anything on nanoscale.
- Scanning tunneling microscopes use a weak electrical current to probe the scanned material.
- Atomic force microscopes scan surfaces with an incredible fine tip.
- Both microscopes send data to computer where information is assembled and visualised on the monitor.

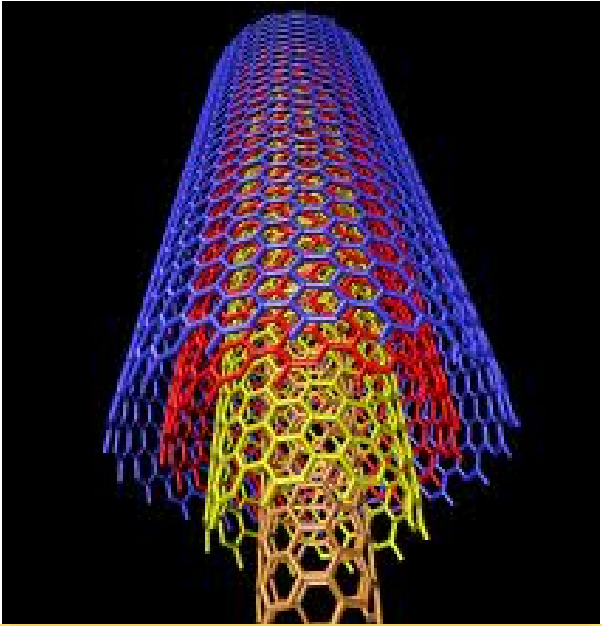
NANOWIRES and CARBON NANOTUBES - I.

- Two nano-size structures seem to be of special interest for computing: nanowires and carbon nanotubes.
- Nanowires are wires with diameter sometimes as small as 1 nm. They seem to be usable to build tiny transistors.
- A carbon nanotube is a nanosize cylinder of carbon atoms.
- Take a sheet of carbon atoms, which would look like a sheet of hexagons, and role it into a tube - you get a carbon nanotube.

CARBON NANOTUBES



CARBON NANOTUBES - I.



NANOWIRES and CARBON NANOTUBES - II.

- Carbon nanotube properties depend on how you role the sheet - how you align the individual atoms.
- For examples, with the right arrangements of atoms one can create a carbon nanotube that is hundred of times stronger than steel, but six times lighter.
- Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1 - sufficiently larger than for any other material.
- Carbon molecule are the strongest and stiffest material yet discovered.
- Carbon nanotubes can also be effective semiconductors with the right arrangement of atoms and they are also expected to be used to build transistors.

CARBON NANOTUBES COMPUTING

Intensive research is nowadays been conducting to show that carbon nanotubes can be a bases for faster and more energy efficient computing.

A lot of breakthroughs has been recently reported in this area.

- In March 2013 IBM Watson reported to assemble 10,000 of 2 nm carbon nanotubes transistors on a silicon chip. However, their nanotubes were still 150nm apart. Next big problem to pack up nanotubes in a much more dense way. Second big problem is how to assemble any desirable large number, say billions, nanotubes.

CARBON NANOTUBES COMPUTING - I.

- In March 2013 in Stanford a computer chip was demonstrated based on transistors made out of carbon nanotubes. It is much more energy efficient.
- At TU München carbon nanotubes were reported, in 2013, to be used as qubits for a quantum computer. Nanotubes can stores information in the form of vibration.
- In Cambridge, 2010, carbon nanotubes based RAM was designed for molecular computing.

NANO(BIO)TECHNOLOGY - I.

- Nanotechnology has potential to completely revolutionize the electronic industry.
- Nanomachines may some day create computer circuits from the "bottom up" - one atom at a time. Moreover, nanocrystalline processes can be used to grow electronics components - nanowires - as small as strings of atom that can grow like crystals and then assembled into circuits.
- Nano(bio)technology is already being used also to design sport tools: tennis rackets, tennis and golf balls, swimming suits,....
- Nano(bio)technology has been considered of such importance for mankind that there was a serious proposal to establish nanotechnology as a human heritage for the coming generations, and develop it as an open technology, based on ethical practices, for peaceful purposes.

NANOROBOTICS and NANO(RO)BOTS

- Nanorobotics aims to design machines or robots whose components are at, or close to, the scale of nanometer (10^{-9}m) - devises of the size 0.1-10 nanometers and constructed of nanoscale or molecular components.
- Nanorobotics is in research-development phase, but some primitive molecular machines have been tested. An example is a sensor having a switch approximately 1.5nm across, capable of counting specific molecules in a chemical sample.
- At Rice university they developed, by a chemical process, a single-molecule "car".
- Main current application of nanobots is seen in medicine for sensing in cells, diagnosing cells, drug deliveries in optimized way, destroyment of cancer cells, surgery instrumentation,...
- At Harvard and MIT they were able to attach special NRA strands, 10nm in diameter, to nano-particles and fill them with a chemotherapy drug. Since these RNA strands are attracted to cancer cells, when a nanoparticle encounters a cancer cell, it adheres to hit a cancer cell and to release drugs into the cancer cell.
- So called Nubots (nucleic acid robots) are organical molecular machines at the nanoscale. DNA structure can provide means to assemble 2D and 3D nanomechanical devices. They can be activated using small molecules, proteins and other molecules of DNA.
- A 2 billion dollars research project was establishes in US to develop nanodevices for medicine.

NANOTECHNOLOGY GOALS and TOOLS

- Nanotechnology promises tools to rebuild the physical and also biological world - including our bodies and brains - molecule by molecule and, potentially, atom by atom or even particle by particle.
- Nanotechnology has the potential to enhance human performance, to bring sustainable development for materials, water, energy and food, to fight diseases and to reverse aging processes.
- Nanotechnology will allow to develop clean, renewable, distributed, and safe energy technologies.
- Fully developed nanotechnology will enable energy requirements for each bit switch to be reduced by about a trillion.
- Key feature size of technology keeps shrinking by a factor 4 per linear dimension per decade. At this rate the key feature sizes for most of electronics and many mechanical technologies will be in the nanotechnology range (that is under 100 nanometers - by 2020s.
- Nanotechnology-based manufacturing could eventually be capable to create almost any physical product from inexpensive raw material and information.
- Biotechnology is currently more advanced than nanotechnology. However, due to inherent sub-optimality of biological systems, biotechnology will never be able to match what is in the potential of nanotechnology once we fully understand principles of biology's operations.

HISTORY

- The origin of the idea to explore nanoscale world is usually attributed to Richard Feynman talk, in 1959, There is plenty room at the bottom.
- Eric Drexler PhD thesis, Engines of creation, 1982, and his following books, in 1986 Engines of creation: The coming Era of Nanotechnology and, in 1992, Nanosystems, are often seen as founding the area and providing its road maps.
- Drexler was inspired by von John Neuman (1956) attempt to reply positively to one of the most puzzling scientific questions at that time, namely Can machines reproduce themselves? and suggested, as the first step, to design a universal constructor, assembler, that could assembly itself once enough parts are available.
- Though Drexler did not provide a detailed proposal for such assembler, his thesis provided feasibility arguments for design of each of the principal components of a potential universal molecular assembler.
- Drexler proposed to use molecular "locks" instead of transistors, with each lock requiring only 16 nn^3 space and could switch ten billion times per second. SIMD architecture was proposed in which a single data store would record instructions and transmit them to trillion molecular-sized assemblers simultaneously.
- The constructor was to be a simple molecular robot with a single arm.
- A very important next step was also the invention of the scanning tunnelling microscope in 1981, by G. Binning an H. Rohrer - Nobel prize, that allowed visualisation of individual atoms and bonds and was used to manipulate individual atoms in 1989.

FURTHER STEPS

- Drexler's proposal inspired many to have as the goal design of an assembler that could manufacture almost any physically possible product for which proper "software" is available.
- The cost of creation of any product would then be only the price of material and energy and therefore value of any product would be reduced, in an essential way, to the price of the program (information) for the assembler.
- The ultimate existence proof of the feasibility of a molecular assembler is the life itself.
- As we deepen our understanding of the information basis of life processes, we are discovering specific ideas that are applicable to the design requirements of a generalized molecular assembler.
- Although Drexler's concept of nanotechnology dealt primarily with precise molecular control of manufacturing, it has been expanded to include any technology key features of which can be measured by few nanometers.

POTENTIAL of NANOPARTICLES in BIOLOGY and MEDICINE

- Nanoparticles are being employed in experimental biological tests as tags and labels to greatly enhance sensitivity in detecting substances such as proteins.
- Successful experiments have been conducted with gold nanoparticles to test rapidly for specific DNA sequences in a sample.
- Emerging microfluidic devices, incorporating nanoscale channels, can run hundred of test simultaneously on tiny samples of a given substance. Such devices will allow extensive tests to be performed on nearly invisible samples of blood.
- Nanoscale scaffolds have been used to grow biological tissues such as skin. This could be used to grow tissues needed for repairs inside the body.
- A particularly exciting application is to use nanoparticles to deliver treatments to specific sites in the body. (In McGill U. demonstrated a nanopill with structures in 25-45 nanometer range.)
- In MicroChip Bedford (US) a computerized device was developed that can be implanted under the skin and delivers precise mixtures of medicines from hundred of nanoscale wells inside the device. (This experience indicate possibilities to have artificial devices for hormone-producing organs.)
- Another idea is to guide gold nanoparticles to a tumor site, then heat them with infrared beams to destroy the cancer cells.

OTHER POTENTIALS of NANOTECHNOLOGY

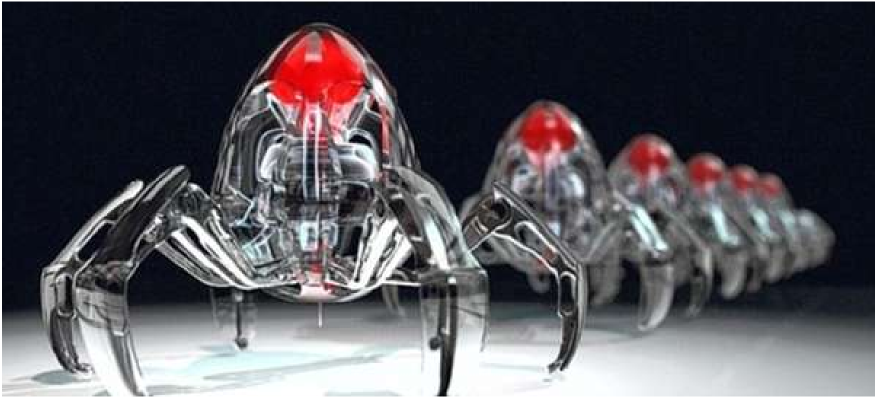
- Nanotechnology is expected to make possible development of clean, renewable, distributed and safe energy technologies.
- Nanotechnology is expected to reduce energy consumption and is expected also to make transmission of energy far more efficient.
- Fuel cells are envisioned that could produce power twice as efficient as gasoline-based engine, producing only water as waste.
- At U. of Texas developed a nanobot-sized fuel cell that produces electricity directly from the glucose-oxygen reaction in human blood.
- Fuel cells have been developed that could utilize actual bacteria or, directly apply chemical reactions bacteria facilitate.
- The most promising approach to nanomaterials-enabled energy is from solar power.

NANOBOTS and their POTENTIAL

- Nanobots (or nanorobots) are small robots that can travel inside the bloodstream. This notion is not as futuristic as it may sound - many such microscale 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.

MODEL of a NANOBOT

NANOROBOTS SWARMS

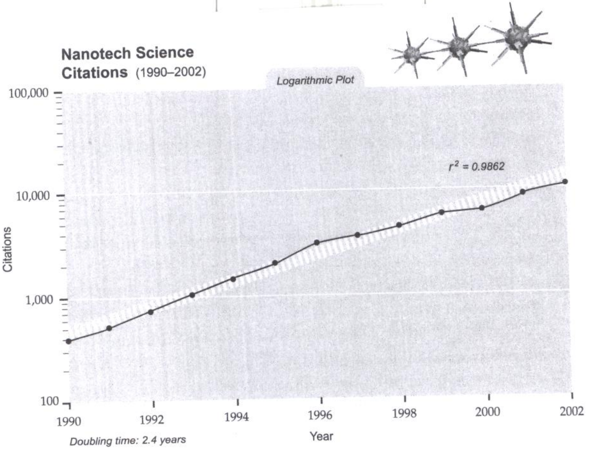


RECENT NANOTECHNOLOGY DEVELOPMENTS

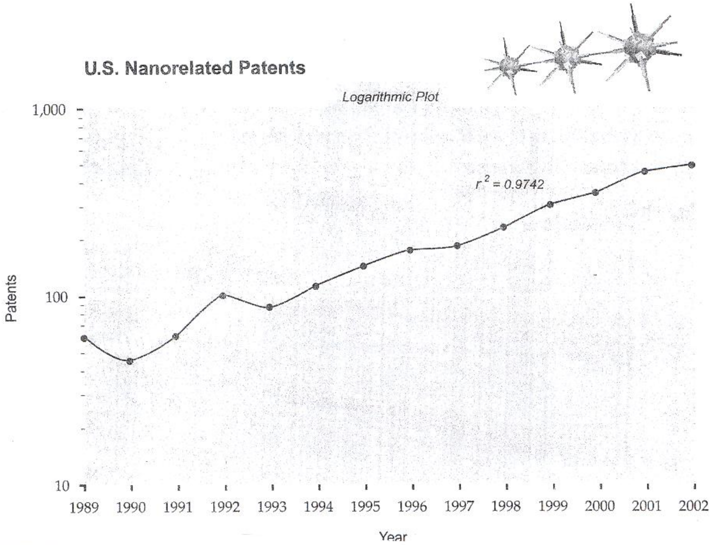
- In 2008, scientists from the University of Manchester announced a transistor 1 atom thick and 10 atoms across;
- In December 2009 a working transistor was announced that was made of a single (benzene) molecule (attached to gold contacts) by a team from Yale University and from South Korea;
- In January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

GROWTH of NANOTECHNOLOGY CITATIONS

The fact that a wide range of technologies move fast to multinanometer range cause rapid interest in nanotechnology. The following figure depicts its reflection in nanotechnology science citations.



NANOTECHNOLOGY ORIENTED PATENTS in US



Robotics and AI

Intersection of technology and informatics

- We know what we are, but know not what we maybe.

  William Shakespeare

- The most important thing is: To be able any time to sacrifice what we are for what we could become.

  Charles Dobois

- Artificial intelligence is the study of how to make real computers to act like the ones in the movies.

  Anonymous

- Who will be man's successor? The answer is: We are ourselves creating our own successors. Men will become to machines what horses and dogs are to men. Conclusion; machines are, or are becoming, animate.

  Samel Buttler, 1863

WISDOMS AI - I.

- Will robots inherit the earth? Yes, but they will be our children.

  Marvin Minsky

- Our machines will become much more like us, and we will become much more like our machines.

  Rodney Brooks

- Yes, we have a soul. But it is made of lots of tiny robots.

  Guilio Giorelli

- We don't have to know how people reason in order to get machines to reason.

  John McCarthy

WISDOMS AI - II.

- The quest for artificial intelligence is as modern as the frontiers of computer science and as old as Antiquity.

  Stephanie Hack

- AI began with an ancient wish to forge the gods.

  Pamela McCorduck

- Pattern recognition and association make up the core of our thoughts. These activities involve millions of operations carried out in parallel, outside of the field of our consciousness. If AI appeared to hit a brick wall after a few quick victories, it did so away to its inability to emulate these processes.

  Daniel Crevier

- The question of whether computers can think is like the question of whether submarines can swim.

  Edger W. Dijkstra

- We need not decide if a machine can "think"; we need only decide if a machine can act as intelligently as a human being.

  Turing's "polite convention".

WISDOMS AI - III. FROM NICK BOSTROM (1997)

Given that superintelligence will one day be technologically feasible, will people choose to develop it? Yes, because:

- Associated with every progress along the road to superintelligence are enormous economic payoffs.
- The computer industry invests huge sums in the next generation of hardware and software, and it will continue doing so as long there is a competitive pressure and profits to be made.
- There is also a strong military motive to develop artificial intelligence.

And nowhere on the path is there any natural stopping point where technophobics could plausibly argue; "hither but not further".

WISDOMS of AI - IV. FROM NICK BOSTROM (2006)

Algorithms originally developed by AI researchers began to appear as parts of larger systems.

However, the field of AI receives little or no credit for these successes.

A lot of cutting edge AI has filtered into general applications, often without being called AI because once something becomes useful enough and common enough it is not labelled AI anymore.

WISDOMS of AI - V. FROM STEVEN PINKEL

The main lesson of thirty five years of AI research is that hard problems are easy and easy problems are hard.

The mental activities of a four-years-old that we take for granted - recognizing a face, lifting a pencil, walking across a room, answering a question - in fact solve some of the hardest engineering problems ever conceived...

As the new generation of intelligent devices appears it will be the stock analysts and petrochemical engineers and parole board members who are in danger of being replaced by machines. The gardeners, receptionists and cooks are secure in their jobs for decades to come.

....

HYPOTHESIS CONCERNING AI

- Every aspect of learning or any other feature of intelligence can be so precisely described that a machine can be made to simulate it.

  Proposal for first AI conference in 1956
- A physical symbol system has the necessary and sufficient means of general intelligent action.

  Newel and Simon's physical symbol system hypothesis.
- The appropriately programmed computer with the right inputs and outputs would thereby have a mind in exactly the same sense human beings have minds.

  Searle's strong AI hypothesis.

LONG STANDING QUESTIONS RELATED to AI

- Should artificial intelligence simulate natural intelligence by studying psychology or neurology?
- Is human biology as irrelevant to AI research as bird biology is to aeronautical engineering?
- Can intelligent behaviour be described using simple, elegant principles? Or does it necessarily requires solving a large number of completely unrelated problems?
- Can intelligence be reproduced using high-level symbols, similar to words and ideas? Or does it require "sub-symbolic" processing?

AI

- AI is the study how to make computers/robots to do things at which, at the moment, people are better.
- Narrow AI - performs useful and specific functions that once required human intelligence to perform, and does so at human levels or so.
- Strong (General) AI - AI that exceeds human intelligence.
- As revolutionary as nanotechnology will be, strong AI will have far more profound consequences.
- Machines are expected to match (and quickly exceed) peak human skills in each area of skills.
- AI at human levels will necessarily fast greatly exceeds human intelligence for a variety reason - machines can aggregate, share knowledge combine computation and communication resources,...and therefore once AI reaches its human level it starts to improve doubly exponential.

OTHER VIEWS of AI

Artificial intelligence is:

- a branch of informatics that studies and develops intelligent machines and software;
- the study and design of intelligent agents;
- the science and engineering of making intelligent machines.

PREHISTORY of AI

- The concept of thinking machine began as early as 2500 BC, when the Egyptians looked to talking statutes for mystical advices.
- Automata, the predecessors of today's robots, date back to ancient Egyptians figures with movable limbs, as those found in Tutankhamen's tomb.
- Philosophers used to consider the possibility of intelligent machines as a literary device to help us to define what it means to be human.
- Science fiction writers, such as Jules Verne, Frank Baum, Isac Anisimov and others used the possibility of intelligent machines to advance the fantasy of the intelligent nonhumans and inspired by that many AI researchers.
- However, only in the last half century AI have been able to build machines that test our hypothesis about the mechanism of thought and intelligent behaviour.
- The term Artificial intelligence was coined in 1956 at the end of two months long Dartmouth conference - the idea from John McCarthy.
- At the same conference Allen Newell, J. C.Show and Herbert Simon demonstrated the first AI program, the Logic Theorist that proved 38 out of 52 basic theorems from Principia mathematica by B. Russel and A. N. Whitehead. For one of the theorems the program found a new and better proof. Logic Theorist was therefore the first 'thinking machine" that new more than its programmers.

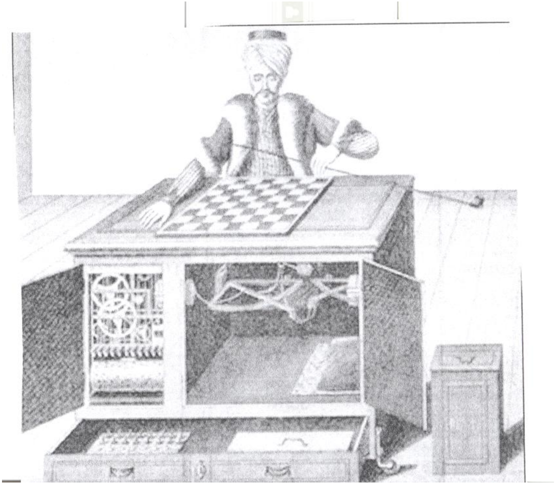
AL-JAZIRI's PROGRAMMABLE AUTOMATA - 1206

Al-Jaziri described a band made of humanoid automata which performed more than 0 facial and body actions during each musical performance.

Al-Jaziri also created hand washing automata with automatic humanoid servants.

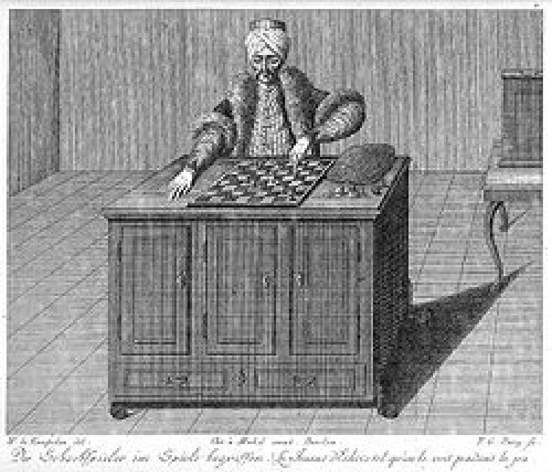
FAMOUS CHESS PLAYING AUTOMATON

At the end of 18th century the following chess playing automaton of Wolfgang von Kempelen (1734-1804) (with a Turk in) could beat rulers in Europe:



FAMOUS CHESS PLAYING AUTOMATON

An engraving of Turk from 1874.



FAMOUS CHESS PLAYING AUTOMATON

Turk reconstruction.

BACKGROUNDS of AI

- AI is based on the assumption that the process of human thought can be mechanized.
- The study of "mechanical" or "formal" reasoning has long history - Chinese, Indian and especially Greek philosophers dveloped already in first millennium BC structured methods of formal deduction.
- In the 17th century Gottfried Leibniz, Thomas Hobbes and René Descartes, started to explore the possibility that all rational thought could be made as systematic as algebra or geometry.
- Leibniz envisioned a universal language of reasoning which would reduce argumentation to calculation so that there would be no more need of disputation between two philosophers than between two accountants, for it would suffice to say to each other (with a friend as witness, if they like), Let us calculate.
- In the 20th century, the study of mathematical logic provided the essential breakthrough that made AI seem possible.

BASIC PROBLEMS and GOALS OF AI

Basic problems of AI can be formulated as follows:

- Knowledge representation.
- Deduction, reasoning and problem solving.
- Planning
- Learning
- Understanding and simulation of creativity,.... as well as emotional and social intelligence.
- Natural language processing
- Perception
- Motion and manipulation skills

A problem is called AI-complete if in order to solve this particular problem, you must solve all other problems. For example, natural language machine translation is seen as such an AI-complete problem.

Predictions of founders of AI:

- Within ten years a digital computer will be the world chess champion, unless rules bar it from competition.

  Allen Newell, 1957

- Within ten years a computer will discover and prove an important new mathematical theorem

  Allen Newell, 1957

- Machines will be capable, within twenty years, of doing any work that a man can do.

  Herbert Simon, 1965

- Within a generation... the problem of creating AI will substantially solved.

  Marvin Minsky, 1967

  In from 3 to 8 years we will have a machine with the general intelligence of an average human being.

  Marvin Minsky, 1970

- Artificial intelligence? IT'S HERE.

  Business week cover, July 9, 1984.

SUMMERS and WINTERS of AI - I.

- One can consider Allen Newell, Herbert Simon, John McCarthy, Marvin Minsky,..... as founders of AI.
- Founders of AI presented prospects of AI as enormous and as those to appear soon. Their expectations have been confirmed by creation a variety of simple programs exhibiting, for many, astonishing intelligence and AI Summer came - a lot of money was put into the AI research worldwide.
- That was followed by surprising performance of some theorem proving and answers providing systems and as consequence many companies believing to make profit of it were established.
- However, when it turned out that it is likely to take far more time till enough powerful AI systems will be available, and profits of such companies did not materialized there was a "bust" in AI since 1973 that became known as "AI Winter", and for some this was seen as the end of AI rush.

SUMMERS and WINTERS of AI - II.

- In 1973 in US and UK funding of AI research was stopped in response to criticism of Sir James Highlight and a pressure from US Congress to fund more productive projects.
- New "AI Summer" came back in 1980 after a big success of Expert systems (by 1985 the market for AI reached over a billion dollars) and after the Japanese "Fifth generation computers" project was announced. Both governments and industry started to put again a lot of money into the AI research.
- New "AI Winter" came by the late 80's, beginning with collapse of the Lisp machine market in 1987, when investors got disillusioned and funding stopped.
- Cycles of boom and bust, of AI winters and summers kept continuing.

WHAT AFTER STRONG AI? - EXPECTATIONS

- One can expect that once strong AI will be achieved, it will start to advance, in cycles, and follow an exponential developments - this should be seen as fundamental nature of machines capabilities.
- Each cycle is expected not only to create a more intelligent AI, but it should need for that less time than the cycle before.
- To summarize, we expect that once strong AI is achieved it will became a runway phenomenon of rapidly escalating super-intelligence.
- A warning. One should not expect that this starts to happen immediately once computer will be able to pass Turing test.

PROBLEMS and GOALS of AI - I. KNOWLEDGE REPRESENTATION

- Knowledge representation: This is a central problem of AI.
- Many tasks AI is to manage will require extensive knowledge about the world.
- AI needs to represent: objects, concepts, properties, categories and relations between objects, situations, events, states and time, causes and effects.
- Some of the most difficult problems in knowledge representation:
- Qualification problem (of things, events,...) and default reasoning.
- Understanding of enough from common sense knowledge - its amount an average person knows is enormous.
- Knowledge for "sub-symbolic reasoning" - to deal with feelings, conscious knowledge and so on that is not represented by "facts" or "statements".

PROBLEMS and GOALS of AI - II.

- Deduction, reasoning and problem solving: Algorithms imitating the step-by-step reasoning, deduction and problem solving of humans failed because of "combinatorial explosion". A variety of new approaches is being developed that imitate more intuition based approaches of human.
- Automated planning and scheduling: Intelligent agents must be able to visualise environment and future, to set goals and achieve them, to check periodically whether the world matches its predictions, to modify plans, to cooperate with other agents. A variety techniques for doing that is being developed.
- Machine learning It is development and analysis of algorithms that improve automatically through experience. Unsupervised learning is the ability to find patterns in a stream of input. Supervised learning deals with classification and regression. Classification is used to determine to which category something belongs. The task of regression is to produce a function that maps given inputs into outputs and predict how the output is to change if input changes.

PROBLEMS and GOALS of AI - III.

- Natural language processing The goal is to give machines an ability to understand, translate and speak natural languages.
- Social intelligence The goal is to develop systems and devices capable to recognize, interpret, process and simulate human affects and emotions and to adopt and respond to them in a way humans are comfortable with.
- Creativity The goal is to study creativity theoretically (from a philosophical and psychological perspective) and design systems that generate outputs that can be considered as creative or to identify creative products.

MAIN PARADIGMS - I.

- In the 1940s and 1950s connections between neurology and information theory, motivated by emerging cybernetics, started to be developed and that resulted also to the design of several electronic networks exhibiting rudimentary intelligence.
- Once digital computers started to be developed the possibility started to be explores, at the end of 1950s, that human intelligence could be reduced to symbol manipulation. Research was dominated by three approaches developed at Carnegie Mellon University, Stanford and MIT.

MAIN PARADIGMS - II.

- At Carnegie Mellon University Herbert Simon and Allen Newell developed cognitive simulation approach to simulate human-solving techniques.
- At Stanford John McCarthy developed logic based approach that focuses on using formal logic to solve AI problems. That led to the development of LISP computer language and then LISP machines and later PROLOGUE and logic programming.
- At MIT Marvin Minsky and Seymour Papert developed an anti-logic or scruffy approach arguing that that there is no simple general principle capturing all aspects of intelligent behaviour.

- Availability of large memory led to a global understanding that large knowledge bases should be inherent part of AI systems. That led to the knowledge revolution and to the development of expert systems.
- By the 1980s an understanding developed that symbolic approach has strong limitations and a variety of sub-symbolic approaches (such as fuzzy systems and evolutionary algorithms) started to be developed.
- In the 1990s a variety of mathematical, especially statistical and operation research techniques started to be successfully applied to the design of AI systems.

COMMENT

- So called intelligent agents paradigm started to be developed during the 1990's. An intelligent agent is a system that perceives its environment and takes actions that maximize its chances for success.

MAIN TOOLS

Let us present main tools, from a variety of tools available, for solving AI problems.

- A variety of powerful search, optimization and evolutionary algorithms and heuristics is nowadays available for finding a targeted goal.
- A variety of special logics has been developed to be used in AI: fuzzy, modal, subjective, default, non-monotonic and description logics and also situation, event, fluent and casual calculi.
- A variety of probabilistic methods for uncertain reasoning has been developed. For example Bayesian networks, hidden Markov models. They are used to deal with such problems as reasoning, planning, learning that require agents to operate with incomplete or uncertain information. A variety of tools from decision and information theory have also been developed how agents can make choices and plans
- Classifiers and statistical learning methods. Classification forms a central part of many AI systems. Classifiers are functions that use pattern matching to determine a closest match. They can be trained in various ways using a variety of statistical and machine learning methods.
- Neural networks. Two categories of neural networks are recurrent (with feedback) and feedforward (without feedback) networks. Hopfield networks and perceptons are their main representatives.

STATE of the ART - NARROW AI

Currently, we are in an era that can be termed as "narrow AI" in which one uses more or less sophisticated AI systems daily to perform, on human level or even far better, concerning quality, speed and reliability, important and complex functions. Some of the most successful broad and widely applied outcomes are:

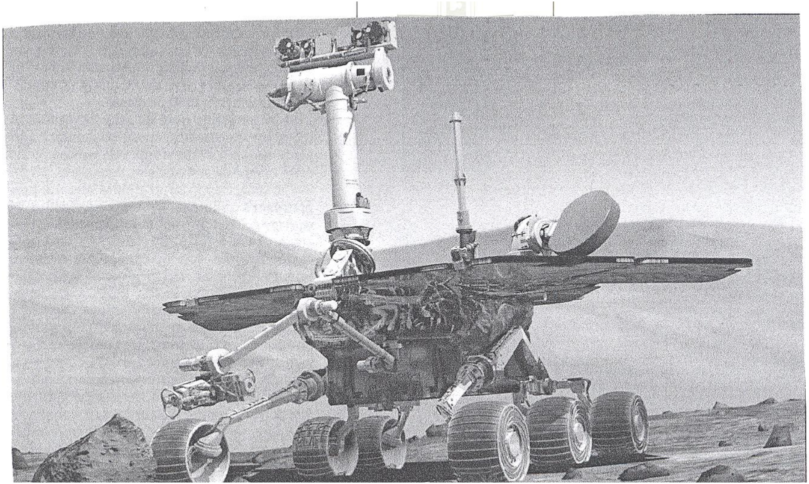
- Systems in charge of mobile and internet communications.
- Flying a plane is from the start to landing and finding a gate guided by AI systems.
- AI weapons of remarkable precisions, and unmanned robotic planes and arms.
- To watch movies one see products of AI systems and when fighting video games on a computer one fights AI systems.
- Google searching is guided by an AI systems

- Chess systems capable to beat world champions.
- A system, called Watson, capable to beat in 2011, two best players in the famous Jeopardy question-answers TV quiz show that runs regularly since 1984 .
- Systems to prove theorems that top mathematicians were not able to do.
- Systems to guide space missions
- Autonomous robotic car winning in 2005 the DARPA Grand Challenge, to get autonomously through a 131 miles long unrehearsed desert trail and to make 55 km in city traffic.
- Robots exploring moon, Mars and other planets.

- Robots capable to navigate, to walk, to dance, to care, to play games, to fight, to entertain, to .....
- Robots capable to assist in performing surgeries.
- Unmanned vehicles and aircrafts.

In addition, there have been more than 2,000 robots "fighting' in Afghanistan alongside with human troops.

MARS ROVER - 2003



Development of systems for game-playing, puzzle-solving, conversation skills demonstrating, Turing test satisfying and so on have been since 1950 one of the main challenges of AI.

SUCCESSES

- In 1994, the program CHINOOK won the World Man-Machine Checkers championship.
- In 1997, DEEP BLUE defeated the World Chess champion Gerry Kasparov.
- In 1997, LOGISTELLO defeated the World Othello Champion Takeshi Murakami.
- In 1998, TD-GAMMON matched wits with World Champion in Backgammon, Malcom Davis.

Huge success has been achieved in solving various sliding-tile puzzles, for example, 15-puzzle (search space $O(10^{13})$), 24-puzzle (search space $O(10^{25})$) and crossword puzzles.

BACKGROUNDS of SUCCESSES

Three factors allowed enormous progress in game-playing and puzzle solving. For example, in 16 years sliding-tile puzzle solving capabilities has been improved by an incredible factor $O(10^{12})$.

- Enormous increase in computers potentials.
- A variety of new search techniques.
- A variety of learning techniques.

- Two-player perfect-information games A big challenge are games Hex, Shogi (Japanese chess) and Draughts (10×10 checkers).

  Go is a megachallenge. Amazon game with difficulty between chess and go - starting position has 2,176 legal moves is also a challenge.

  On 20.3.2013 program Crazy stone, by Réne Conton, defeated go professional, Ishido Yoshio 9p, with a 4 stone handicap.

- **Imperfect-information and stochastic games**
  Poker and bridge are still big challenges.
- Since 2006, Annual Computer Poker Championship is held. In July 3-6, 2008 program Polaris, from Texas, played against 6 professionals with 3 wins, 1 tie, 2 loses.
- Computer bridge playing is considered to be in infancy. In spite of the fact that in 2007 the World Computer Bridge Champion Jack lost to 7 top Dutch players and 2 European champions as 356;385 imps.
- Annual World Computer Bridge Championship takes [lace since 1997 and improved Jack won also in 2012.

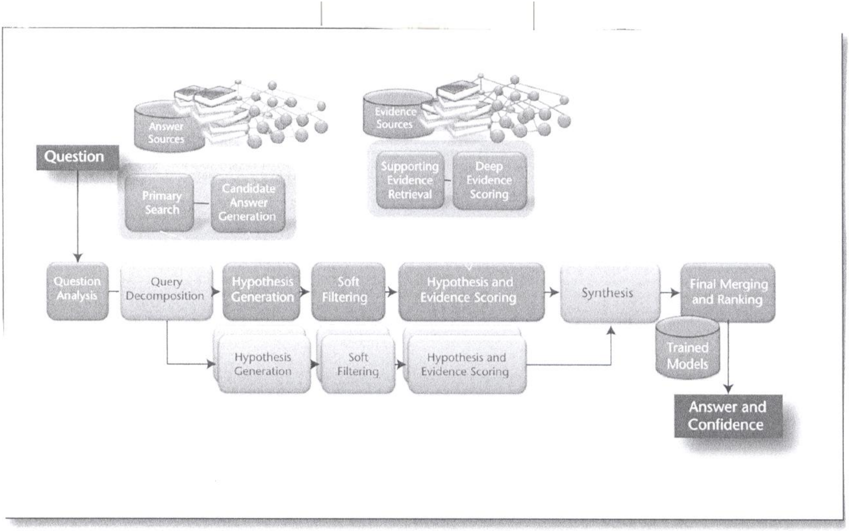
CHESS STORY in BRIEF

- On May 11,1997 Deep Blue of IBM defeated Gary Kasparov in 6 games.
- Deep Blue run on a 256 special-purpose chess processors computer and could analyse $2 \cdot 10^8$ board positions per second.
- Deep Blue was based on CMU's Deep Thought that could analysed 1 million board positions per second and achieved ranking 2700. This machine was based on HiTech that could analyse 175,000 board positions per second and achieved ranking 2400 (World champion was about 2800).
- In 2003 Deep Fritz achieved a draw with Vladimir Kranik, inspite of the fact that it analyse only 2.5 million of board positions per second.
- However, Deep Fritz run a non-specialized computer and had only 1.3% of the brute force of Deep Blue. However it had better patter-recognition algorithm.
- Rating from 2004; Kasparov 2795, Kranik 2794.
- Rating from April 2013: Carsen 2874, Aronian 2809, Kramik 2801, Annan 2783

JEOPARDY QUIZ - GREAT SUCCESS of AI

- On February 14, 2011 and February AI system Watson, implemented on DeepQA architecture, won competition with two superplayers of the Jeopardy game.
- To win such a game Watson had to demonstrate extraordinary "intelligence". Namely, a capability to understand very well natural language sentences and to express itself in natural language questions.
- In the game players get a series of tricky answers and have to find likely questions that could have such answers, in 3 seconds for each "answer/clue".
- Watson had in 4 terabytes memory 200,000,000 pages of text.
- IBM announced in February 2013 first commercial application: Utilization management decisions in lung cancer treatment at Memorial Sloan-Kettering Cancer Center.

WATSON's STRUCTURE



JEOPARDY - WATSON versus Jennings and Rutter

JEOPARDY - winner

WHY IT TOOK SO LONG FOR AI TO MATURE

There are several main reasons for that:

- AI revolution is the most profound transformation the human civilisation will experience, so it will take longer to mature than less complex technologies. AI can be characterized by the mastery of the most important and powerful attribute of human civilisation - intelligence.
- AI paradigm started to be pursued when enabling technologies, new paradigms shifts, namely ICT, genetics and nanotechnologies, were only in a very preliminary stage of developments - in short when enabling bio-, nano- and information processing and communication technologies have not been mature enough.
- It is the nature of technology that, at the first stage of its development, an understanding of phenomena is the main issue, but when this is achieved then technology development focus on using and amplifying its power. Currently, every aspect of understanding, modelling and simulating human brain is accelerating: the price-performance and temporal/spatial resolutions of brain scanning, the amount of data and knowledge available about brain regions and functions as well as sophistication of models and simulations of the brain regions.

TO BE AI or NOT TO BE AI

Observation: Watson to Sherlock Holmes: I thought at first you had done something clever, but now I see that there was nothing in it after all.

- One problem with AI: As soon as an AI technique works, it is no longer considered AI, and is seen its own field (see speech recognition, machine vision, robotics, medical informatics,....).
- Roodney Books, director of MIT AI lab: Every time we figure out a piece of AI, it stops being magical and we say: *Oh, that is just a computation"*.
- To summarize: the enchantment of intelligence seems to be reduced to "nothing" when we fully understand its methods. The mystery that is left is the intrigue inspired by the remaining, but as yet not well understood methods of intelligence.

AI's TOOLKIT - I.

At the beginning AI developed a variety of methods that were not based at all on reverse engineering natural intelligence.

- Expert systems They flourished in 1970s. They are systems using special decision-making rules, codifying decision-making thinking of experts, to simulate decision-making process of human experts.
- For example system MYCIN was to be used for diagnosing infection diseases and recommendation of treatments.
- Systems in 1980s started to use also probabilistic rules as the ones that are often the only available for dealing with complex situations and uncertainty involved in them.
- An enormous success was the expert system MYCIN, developed at CMU for DEC company and it was claimed that it was saving the company 40 millions of dollars annually by 1986.
- System CYC of Cycorp, initiated in 1984, has been coding common sense knowledge to provide machines with an ability to understand the unspoken assumptions underlying human ideas and reasoning. Recent big goal was to master 100 million of things - a number a typical person knows about the world.
- Belief nets. Systems are based on Bayesian logic and intend to determine likelihood of future events based on similar occurrences in the past. Systems of this type gather data from experience, keep learning and improving their decision making. Technique turned out very successful when applied to designs spam filters.

AI's TOOLKIT - II.

- Markov chains provide tools to determine the likelihood that a sequence of events would occur. A very successful application of this method was in speech recognition.
- Neural nets is self-organizing and self learning method based on a simplified, threshold firing, model of neurons and inter-neural connections. It has been successfully used for dealing with speech recognition and other pattern-recognition tasks. Original simple nets of this type keep improving using the outcomes of the reverse engineering of human brain. Of special importance have been so called Hopfield nets introduced in 1982.
- Genetic algorithms. They emulate evolution, including sexual reproduction and mutations. Here is the basic idea. A set of possible solutions is randomly generated. Each is evaluated according given criteria. Best of them are left and form their pairs (sexual reproduction by mutation) new ones are created and then multiplied. This processes is iterated. Genetic algorithms are increasingly used to solve otherwise unfeasible optimization problems.
- Recursive search, especially in game trees, for the best moves. Such trees are usually huge and so the key of success is a proper pruning of the tree and ultimately stopping of its grow.

AI's TOOLKIT - III.

- Intelligent agents A new paradigm of intelligent agents was borned when concepts from the decision theory and economics were brought into the development of AI - when the economics concept of a rational agent was married to the CS concepts of objects or module. An intelligent agent is a system that perceives its environment and takes actions which maximizes its chances for success.
- Combination of methods The most powerful approach to building a robust AI system is to combine various methods - so does human brain. The key for success is how to combine methods and to learn from their outcomes and to give them proper weights. Of importance has been also when important tools of decision theory, operational research, probability theory, Bayesian networks, markov chains, stochastic modelling and classical optimization have been brought to AI research and development.

NARROW AI SAMPLER - I.

- Military AI systems. Military used to be main pusher and user of AI systems. A sample of them. Patter-recognition systems to guide autonomous weapons such as cruise missiles. Expert systems to optimize complex supply chains in rapidly changing battlefield situations. Unmanned flying robotic vehicles - that destroyed thousands of tanks and missile sites; robots to search caves and buildings. Moving soldiers away from battles is a rapidly growing trend.
- Space exploration Since communication between spacecrafts to much distant planets and earthbound controllers is much delayed, software controlling activity of spacecraft has to have AI features: capability to perform its own tactical decision; to have models of software's own capabilities and of those of the aircraft. This approach enabled already in 1999 to use its own technical knowledge to create a series of plans to solve an emergency situation that threatened to destroy the mission.

  In addition, NASA used genetic algorithms to design various systems and machines. For example an antenna for Space Technology 5 satellites. Moreover various semi-intelligent observation systems have been designed

NARROW AI SAMPLER - II.

- Medicine AI systems are used to provide diagnosis from electrocardiograms and for other patterns providing systems. Every major drug developer uses AI programs to do pattern-recognition and intelligent data mining in the development of new drug therapies.
- Mathematics. Various provers and proof verifiers have been developed and already in 1999 a long-standing conjecture in Boolean algebra due to Herbert Robbins, that resisted efforts of mathematicians for 60 years, was proved in Argonne National Laboratory.
- Science engineering A "robot scientist" was dveloped at U. of Wales that combines an AI-system to formulate theories; a robots to carry corresponding experiments and a reasoning system to evaluate results.
- Business and finances Companies in almost any industry are using AI systems to control and optimize logistic, detect financial fraud (say in credit-cards transactions) and monetary laundering, and perform intelligent data mining on the base of information they gather each day. For example, data mining allows them to make fairly accurate predictions for requirements of each product, each store and each day. Smart-airport Operation System optimizes, using genetic algorithms, the complex logistic of an airport and raised productivity by about 30% in airports it has been implemented. DARPA claimed that AI-based logistic-planning systems resulted during Desert Storm war in Iraq in more savings than the entire government research investment in AI over several decades.

NARROW AI SAMPLER - III.

- Manufacturing and robotics Computer-integrated manufacturing increasingly uses AI system to optimize the use of resources, streamline resources and reduce inventories through just-in-time purchasing of parts and supplies.Robots are very intensively used in manufacturing. An AI-based material handling cart first analyses situation to find an optimal way to move and to carry its mission. In military situation autonomous vehicles can carry precisely their mission in rapidly changing environments and battlefield conditions. machine vision is improving the ability of robots to interact with humans.
- Speech and language Dealing with natural languages is the mos challenging task of artificial intelligence.
  - Search technologies, such as Google, revolutionized access to information and knowledge and that way revolutionized our ordinary life, learning and science. They use statistical-learning methods and logical inference to determine ranking of links.
  - A natural-language search engine Ask MSR tries to answer natural-language questions. A special search engine finds matches based on he parsed questions.
  - Natural-language systems combined with large vocabulary speaker-independent speech recognition over the phone are entering the market to conduct routine translations. British Airways virtual agent for booking flights are of that type.
  - Language translation systems starts to be better and better and good enough for performing business.
  - In 2003 Franz J. Och dveloped a technique to generate a new language-translation system between any pair of languages in a matter of hours or days - provided he gets a text in one language and its translation in another one (but of the length of about a million of words).

NARROW AI SAMPLER - IV.

- Sport and entertainment: A lot of AI-systems is used to create visions of complex phenomena. In case of sport, of a broad use are systems capable to extract from the transmissions of games their most interesting parts.

SWARM INTELLIGENCE - I.

- A swarm is a large number of of homogeneous, simple agents interacting locally among themselves and with their environment with no central control to allow a global interesting behaviour to merge.
- Swarm-behaviour-based algorithms have recently emerged as a family of nature-inspired, population based algorithms that are capable of producing low cost, fast, and robust solutions various complex problems.
- Swarm intelligence is a branch of AI that is used to model the collective intelligent behaviour of social, decentralized and self-organized, swarms in nature such as ants colonies, honey bees, birds flocking, animal herding, bacteria growth and fish schooling.
- Swarm intelligence can also be seen as an application of swarm behaviour principles and algorithms to the study of artificial intelligence systems.
- On a more abstract level, swarm intelligence systems can be seen as a population of simple agents interacting locally with one another and with their environment.
- The agents of swarms follow very simple rule sand although there is no centralized control structure dictating how individual agents should behave, locally and to a certain degree random, interactions between agents lead often to an emergence of "intelligent" global behaviour, unknown to individual agents.

APPLICATIONS of SWARM INTELLIGENCE

- US army is investigating swarm intelligence methods for controlling unmanned vehicles.
- NASA is investigating the use of a swarm technology for planetary mapping.

FROM NARROW AI to STRONG AI

NARROW AI is GETTING LESS and LESS NARROW

Narrow intelligence is getting fast less and less narrow. Indeed:

- Step by step we are achieving tasks that we used to consider as needed strong AI to achieve and we start to see them as belonging to the merits of narrow intelligence.
- Quite a few years ago computers performing complex computations 1000 time faster than humans were seen as **Giant brains** - because they were able to realize processes beyond animals, that needed human intelligence and years of training.
- Playing chess better than humans, once a benchmark for strong intelligence, is already seen as belonging to narrow AI because "only brute force is needed to achieve it"
- Computers can nowadays surpass humans in such tasks as theorem proving, table tennis playing, planes flying, universe observing, and even in so sophisticate competitions as famous Jeopardy, where very intelligent understanding of natural language and of the rich repertoire of human knowledge played the key role, and we still keep talking about narrow AI.
- To summarize, narrow AI is getting surprisingly fast more and more narrow and stronger and stronger.

PREREQUISITES for STRONG AI are GETTING CLOSER and CLOSER

In two main factors prerequisites for strong AI getting closer and closer.

- Progress in reverse engineering of the human brain is getting faster faster.
- Performance of ICT keeps increasing exponentially and is closer and closer to the state to have potential to beat human brain in its information processing power. Petaflops supercomputers are here and to achieve exaflops computations using networks of supercomputers is also realistic. In addition, the progress in the brain simulation research is also driven by prospects to develop super-fast brain-inspired computers.
- We already have an effective toolkit for narrow AI. Ongoing refinements of these methods, the development of new ones and by combining multiple of methods into intricate architectures narrow AI will become less narrow. Progress in reverse engineering , modelling and simulation of human brains is expected to bring new elements into the AI toolkit and new paradigms for AI. We can expect such a toolkit will be much enriched and inspired by insights from reverse engineering of human brains and especially will be enriched by sophisticate learning methods.

NEW TESTBEDS for STRONG AI

- Turing test, and its numerous variations. (Observe that there is annual Loebner Prize contest in chatterbots (conversational tests) able to convince human judges that it is a human.) So far it has been awarded only bronze prizes - silver prize would be for passing Turing test and golden one would require visual and auditory communication.
- Reviewing movies.
- Holding a press conference.
- Making witty observations at cocktail parties.
- Writing books.
- Creating fancy art.

Observation 1: As long as there are any discrepancies between human and machine performance, strong AI skeptics will seize on these differences.

Observation 2: Our perception of the quality of performance will shift quickly from pathetic to daunting as the knee of the exponential curve is reached for human capability.

Observation 3. For all thresholds, such as Turing test, it is actually very nontrivial to define exactly when a system can be considered as passing the criteria. It is even non-trivial to specify in this context who should be considered as human - could a human intelligence be allowed to have non-biological thinking processes implemented in his brain?

ADVENT of STRONG AI

The advent of strong AI is expected to be the most important transformation this century will see. It will be comparable in importance to the advent of biology itself.

It will mean that evolution of biology has finally mastered its own intelligence and discovered means to overcome its limitations. Once the principles of operation of human intelligence are understood, expanding its ability will be conducted by humans whose own biological intelligence have been greatly amplified through an intimate merge with non-biological intelligence.

Ray Kurzweil, 2004: We are going to merge with our technology. We have already started to do so in 2004, even if most of the machines have not been yet inside our bodies and brains. Our machines nonetheless extend the reach of our intelligence. extending our reach has always been the nature of humans.

It is true that a contemporary human is a collection of cells, and that we are a product of evolution, indeed its cutting edge. But extending our intelligence by reverse engineering it, simulating it, re-instantiating it on more capable substrates, and modifying and extending it is the next step in its evolution. It was the fate of bacteria to evolve into a technology creating species, and it is our destiny now to evolve into the vast intelligence of the Singularity.

- Robotics is a brange of technology that deals with the design, construction, operation and application of robots.
- A robot is a machine, or a virtual artificial agent, usually an electro-mechanical machine, that is guided by a computer program or electronic circuitry.
- Intelligence is required for robots to be able to handle such tasks as objects manipulation, motion planning, path planning, motion navigation and performing, human communication and so on.
- Many of today's robots are inspired by nature creating the field of bio-robotics.

- Unless there are slaves to do the ugly, horrible, uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure and demoralizing. On mechanical slavery, on the slavery of the machines, the future of the world depends.

  Oscar Wilde (1854-1900)

  The world of the future will be an even more demanding struggle against limitations of our intelligence, not a comfortable hand mack in which we can lie down to be waited by our robot slave.

  Norbert Wiener

- Speech in front of a gathering of robots:

  Robots of the world, you are ordered to exterminate the human race! Do not spare the men. Do not spare the women. Preserve only factories, railroads, mines and raw material. Destroy everything else. Then return to work. Work must not cease.

  Karel Čapek

- I believe that robots should only have faces if they really need them.

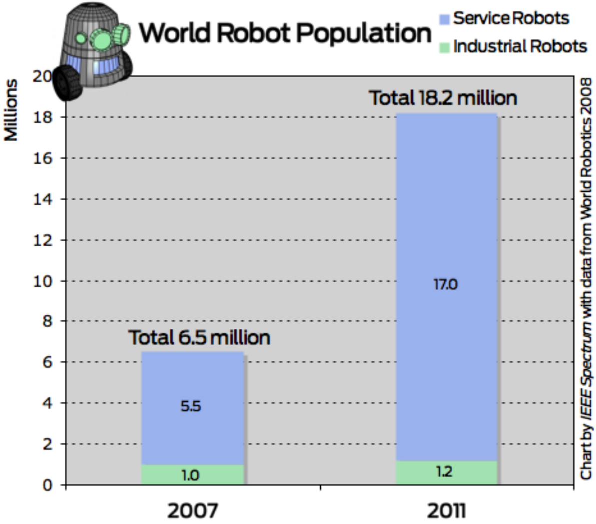
  Donald Roman

ROBOTICS as an EMBODIMENT of a STRONG AI

From three revolutions paving the way to Singularity of far the largest importance is the revolution leading to the development of Strong Artificial Intelligence (AI), what is hidden in the acronym GNR under "R" - under Robotics.

- By "strong AI" a level of non-biological intelligence is understood that is more advanced/powerful as unaided human intelligence.
- Main reason for "hiding" strong AI under "Robotics" is this is a better selling word and, more profoundly, a popular belief is that intelligence needs an embodiment, a physical presence, to affect the real world.
- The last assumption is, however, questionable for two reasons:
  - We can assume that strong AR will find its own means for an embodiment and manipulation of the physical world.
  - We can, and should, consider physical skills as an inherent part of intelligence. Indeed, more than half of our brain, cerebellum, is devoted to coordination of our muscles and to our physical skills.

WORLD ROBOT POPULATION



Current world distribution of robots

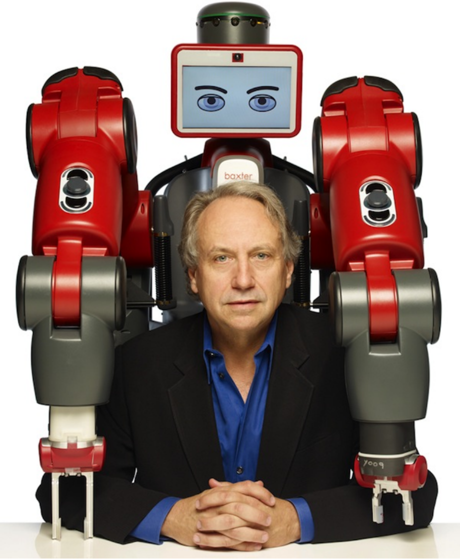
- 40% Japan
- 32% Europe
- 16% North America
- 10% Asia-Japan
- 1% Australasia
- 1% Africa

South Korea is the first country with a program to have a robot at each school.

SPECIAL TYPES of ROBOTS

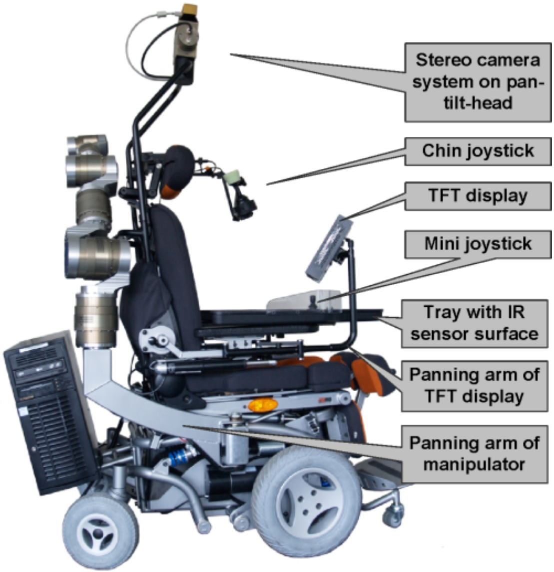
- Collaborative robots - cobots: They are robots that can safely and effectively interact with humans in performance of simple industrial tasks. For example, *Rethink Robotics* introduced, in 2012, an industrial robot Baxter, 22,000 $, to safely interact with neighbouring humans and programmable to do simple tasks.
- Health care robots. They have four functions. (1) To assist individuals; (2) To help in hospitals; (3) To help pharmacies to fill prescriptions; (4) To assist in surgeries. For example, in Bremen university a semi-autonomous robot FRIEND was designed to support disabled and elderly people in their daily life

BAXTER - I.



BAXTER - II.

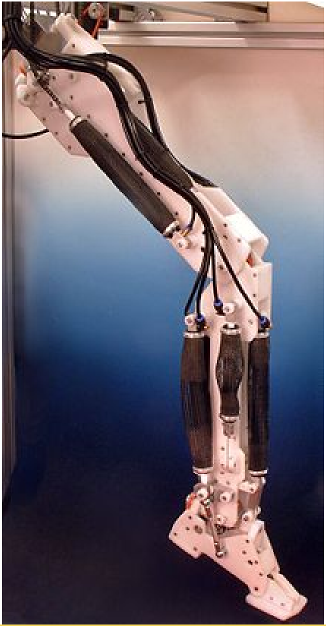
ROBOT FRIEND - INTELLIGENT MOVING CHAIR



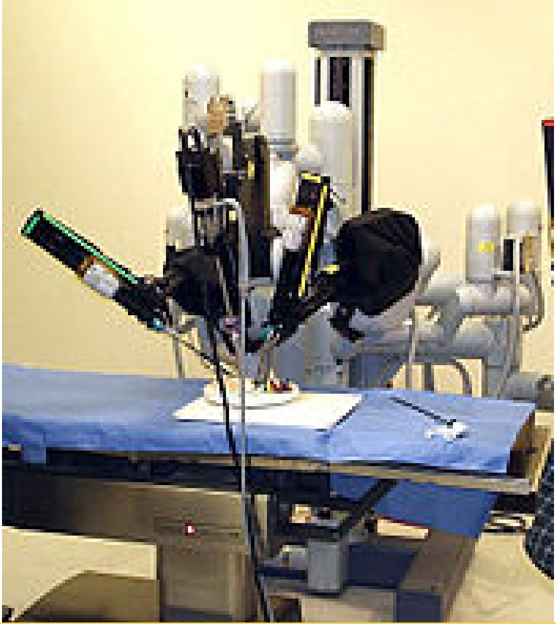
EXAMPLES of INDUSTRIAL and SPORT ROBOTS

VACUUM CLEANER ROBOTS ROOM BA

ROBOTICS LEG



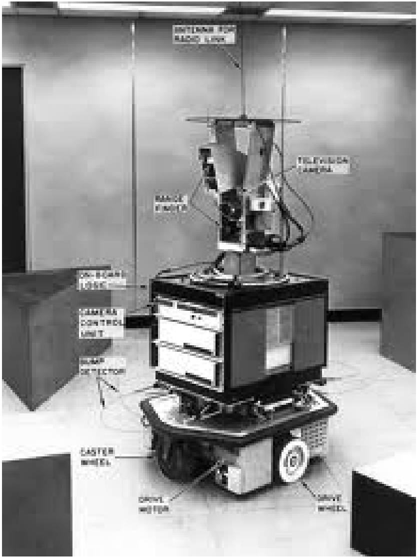
A SURGICAL ROBOT



A PICK and PLACE ROBOT

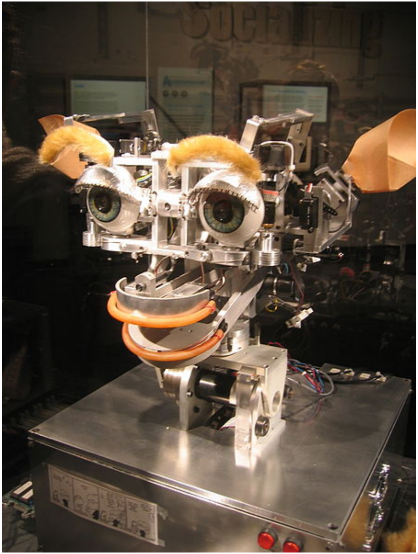
KUKAI INDUSTRIAL ROBOT

SHAKEY ROBOT



The first mobile robot to be able to review its own actions.

KISNET ROBOT



Kismet robot that can produce various facial expressions.

AIBO - CYBER-DOG - a pet robot

ROBOTIC SNAKES

SWARMS of ROBOTS

ROBOTS EMULATING PHYSICAL CAPABILITIES of HUMANS

A huge effort has been oriented to design very skillful hands, robots walking well also on stairs or uneven terrain.

Concerning the overall physical skinless of robots orientation has been to design dancing and rescue robots as well as robots playing various games.

There is a variety of annual RoboCup competitions. For example, several "leagues" in soccer, competitions in dancing and in rescue operations.

The official goal of the RoboCup project is: by mid 21st century a team of fully autonomous humanoid robot soccer players should win the soccer game, complaying with the official rules of the FIFA, against the winner of the most recent World Cup."

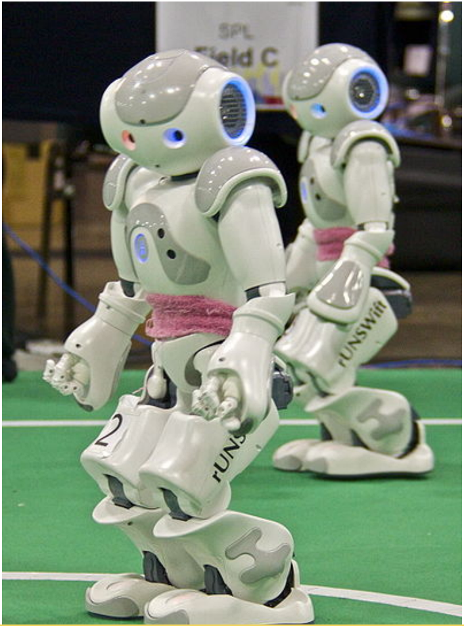
At RoboCup 2012 in Mexico City 381 teams participated from 42 countries and 2356 was the overall number of participants.

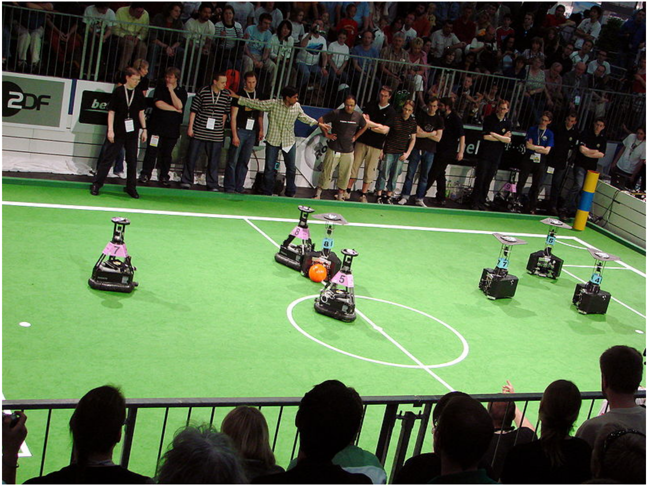
DANCING ROBOT - I.

DANCING ROBOT - II.

Partner Ballroom Dance Robot PBDR

SOCCER PLAYERS from RECOUP 2010

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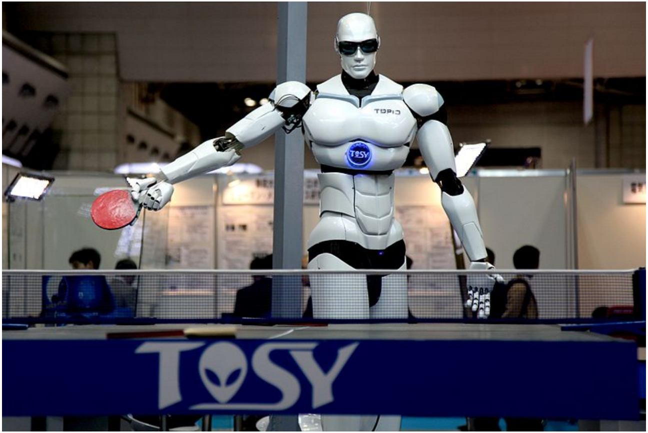
TOPIO - PING PONG PLAYING ROBOT



TOPIO ping-pong playing robot from Vietnam, playing at International Robot Competition in Tokyo in 2009. 39 degrees of freedom, 188cm, 120kg

- In addition to drones most known are unmanned combat air vehicles that can do various missions, especially to carry things in hard to get in terrains and to make reconnaissance services. Some are heavy, but some have only 4 kg.
- As examples; SWORDS robot is used in ground-based combat. It can use a variety of weapons and there is some discussion to giving it some degree of autonomy in battleground situations. Robots Pack bot and TALON have been used in Iraq and Afghanistan to defuse roadside bombs or improvised explosive devises. Robot MULE is to carry heavy things in the terrain with hard access:

MILITARY ROBOT SWAM

Three laws of robotics

Isaac Asimov in his book "I, robot" formulated the following Three laws of robotics:

1. "First Law: A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. Second Law: A robot must obey the orders given by human beings, except where such orders could conflict with the First Law.
3. Third Law: A robot must protect its own existence, as long as such protection does not conflict with the First or Second Law.

TALLON MILITARY ROBOT

Robots used by US army.

ALL TERRAIN ROBOTS

DELIVERY TELE ROBOT

A US army technician prepares a tele robot to detonate a buried improvised explosive device in Iraq.

MULE ROBOT

CASE STUDY I. - STUDY I. - ROBOTICS and WARFARE - I.

There is perhaps no other area of society than warfare that so much pushes and uses developments in AI.
Main reasons for that seems to be:

- Employment of AI and robotics is seen as main factor to achieve supremacy in warfare - concerning power, precision, time and so on.
- **Necessity to diminish human causalities leads to highly intelligent, precise and unmanned weaponry and this way to have much less of undesired side effects - as in medicine.**
- Necessity to diminish the overall expenses leads again to use of AI systems for all levels of war activities.
- The overall tendency to move to an armed force that is "highly responsive, network-centric, capable of swift decision superior in all echelons and able to provide overwhelming massed effects across any battle space".
- Future Combat systems should be "smaller, lighter, faster, more lethal, and smarter".
- When everything will be information, the ability to control your own information and disrupt your enemy's communication, command and control will be a primarily determinant of military success.

CASE STUDY I - ROBOTICS and WARFARE II.

State of the art and goals:

- Sophisticated AI systems are employed for training on all levels and positions in army, navy and air force.
- Unmanned fighting planes and aerial vehicles (called "drones') as well as robotics mules are to be more powerful, can be smaller and cheaper.
- Communication with soldiers should be improved with goal to have direct neural connections.
- A vision is to have armed forces largely robotics with larger level of autonomy.
- A potential use of the swarm intelligence is intensively explored. (in 2003 DARPA announced that a battalion of 120 military robots was to be fitted with swarm-intelligence software to enable it to mimic the organized behaviour of insects).
- Smart dust development. DARPA is developing devices tinier than birds and bumblebees called "smart dust" complex systems not much bigger than a pinhead. The idea is that millions of them would be dropped to enemy territory to provide detailed surveillance and to support offensive warfare missions.
- Nano-weapons will make obsolete weapons of large scale.
- Virtual-reality environments are being used to control remotely guided systems such as Predators - unmanned air fighter.

DRONES

Famous unmanned drone, 8.4m long, that can carry and delver a heavy bomb

Famous unmanned drone, 8.4m long, that can carry and delver a heavy bomb They can search terrain and fire on target.

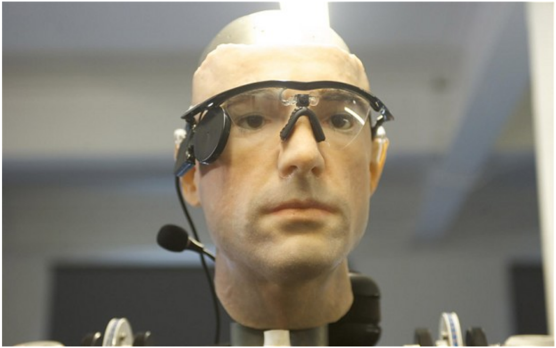
A DRONE in an ACTION

HUMANOIDS and ANDROIDS

- A humanoid robot is a robot with its body shape built to resemble that of human body.
- An android is a humanoid robot built to aesthetically resemble humans.
- A good understanding of human body is needed to built humanoids and building humanoids help to understand better human bodies.
- The initial goal of humanoid research was to build better orthoses and prosthesis - with remarkable achievements.
- Humanoids are built also to perform human tasks: to assist sick and elderly and to perform dirty and dangerous jobs.
- Androids are getting increasingly popular for providing entertainment: Android Ursula sings, play music, dances and speak to her audience in Universal studios.

REX

In February 2013 a model of a bionic man, called REX, with bionic arms (with 26 degrees of movement that can teach itself to work) and legs, artificial battery powered heart, lungs, kidney, pancreas, blood, glasses which send images to a microchip in the retina which then sends electrical impulses to the brain.



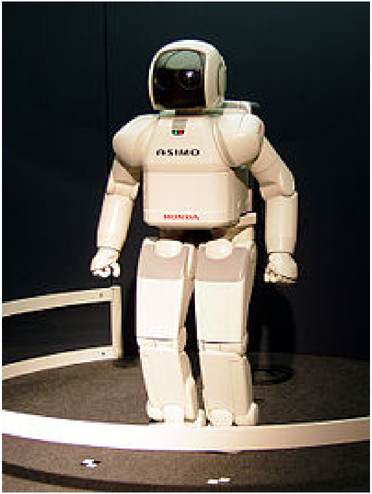
REX I.

The Rex project was to celebrate ..... aniversary of the novel Frankenstein.

VARIOUS HUMANOIDS

ANDROID GIRL DOE1

ROBOT ASIMO



ASIMO (2000) is liekly the best known robot, capable to walk on stairs, run 9km per hour,......

KOREAN EveR1 - 2003

EveR1 could express human emotions, make conversation in Japanese and in English.

KOREAN EveR2 - 2006

Ever2 had in addition an ability to sing.

KOREAN EveR1 - 2009

SOME of INTERESTING ROBOTICS ACHIEVEMENTS - I.

- c. 250 BC Chinese Lie Zi described several automata.
- c. 50 AD Greek mathematician Hero of Alexandria describe a machine to automatically pour wine for party guests.
- 1495 Leonardo da Vin ci described design of a humanoid automaton to look like an armored knight.
- 1738 Jacques de Vinson built The flute player, a life size figure of a shepherd that could play twelve songs on a flute and also a mechanical duck that could flap wings, swallow food from the exhibitor's hand and then produce excrements.
- c. 1850 Hiroshi Tanaka (1791-1881) created extremely complex mechanical toys: some of which served tea, fired arrows drawn from a quiver,....
- 1898 Nikola Tesla designed a radio controlled boat boat.
- 1948 W. G. Walter from Bristol designed first electronic autonomous robot.
- 1954 George Deval constructed first digital and programmable industrial robot Unimate that was then installed, 1961, on a General Motors assembly line to lift hot pieces of metal.
- 1973 In Waseda university, Tokyo, robot Wabot-1 was built capable to walk, to communicate with a person in Japanese and to measure distances and directions using artificial ears, eyes and mouth.
- 1985 Waseda University WASBOT performed a concert with the NHL Symphony Orchestra at the opening ceremony of the International Science and Technology Exposition.

SOME of INTERESTING ROBOTICS ACHIEVEMENTS - II.

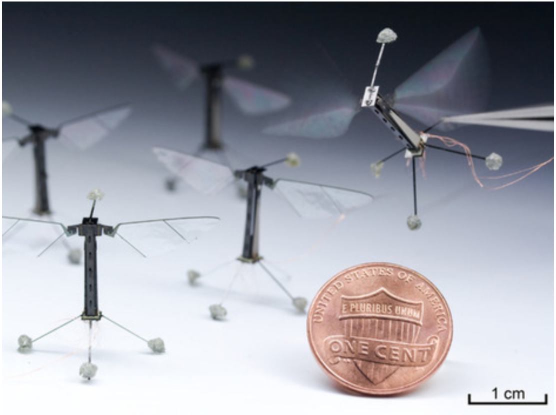
- 2000 Honda created its 11th bipedal humanoid robot ASIMO, capable to run.
- 2005 Mitsubishi Heavy Industries built a domestic robot Camry to provide companionship to elderly and disabled people.
- 2007 TOYS Robotics produced ping pong playing robot TOPIO.
- 2009 Waseda university robot Jobina capable to walk, talk and mimic emotions.
- 2010 In Japan a humanoid robot HARP-4C was built capable singing and dancing along with human dancers.
- 2011 Honda built second generation Asimo robot with semi-autonomous capabilities.

BIG ROBOTICS PROJECTS

- National Robotics Initiative announced in 2012 by president Obama. 20 mil. $ from US government,... Main goals is the design of robots that can:
- increase the productivity of workers in manufactoring sector;
- assists astronauts in dangerous and expensive missions;
- help scientists to accelerate discovery of new life-saving drugs;
- improve food safety by rapidly sensing microbiological contamination.

VERY RECENT NEWS

- In Harvard University they destroyed an insect-robot that can fly like an insect and its weight is less than 1 gram. The main goal was to learn how insects fly. Potential applications are numerous.



FLYING INSECT

APPENDIX

ETYMOLOGY

- The Czech painter and writer Josef Čapek coined the word robot.
- The word robot was introduced to public by Josef Čapek brother Karel in his play R.U.R (*Rossum's Universal Robots*) published in 1920. The issue was exploitation of machines made in a factory for artificial people called robots.

WHAT IS INTELLIGENCE

- Intelligence is the ability to solve problems with limited resources, including limitations of time.
- More intelligent processes will inherently compete ones that are less intelligent, making intelligence the most powerful force in universe.
- The standard reason for emphasizing robotics in NR revolution and not strong AI is that intelligence needs an embodiment, a physical presence, to affect the world.
- We can include physical skills as a fundamental part of intelligence; a large portion of the human brain (the cerebellum, compromising more than half our neurons), for example, is devoted to coordinating our skills and muscles.

Ray Jewel

WHAT IS INTELLIGENCE - I.

- I know I am intelligent, because I know that I know nothing.

  Socrates

- Intelligence is the wife; imagination is mistress; memory is servant.

  Victor Hugo

- It is not that I am so smart, it is just that I stay with problems longer.

  Albert Einstein

- To think is to practice brain chemistry.

  Dee pack Chop run

- Intelligence is what you use when you don't know what to do.

  Jean Piaget

- Intelligence is the ability to adopt to changes.

  Stephen Hawking

- Intelligence is (a) the most complex phenomenon in the Universe; or (b) a profoundly simple process. The answer, of course, is (c) both of the above. It's another one of those great dualities that make life interesting.

  Ray Kurzweil

TURING TEST

- In 1950 Allan M. Turing proposed, in his essay "Computing machinery and intelligence a test to find out whether a computer is intelligent.
- The test calls for a panel of judges to review typed answers to any question that has been addressed to both a computer and a human.
- If the judges can make no distinction between the two answers, the machine may be considered intelligent.
- The Turing test was the first serious proposal in the philosophy of AI.

COMMON SENSE

- Common sense is genius dressed in its working clothes.

  Ralph Waldo Emerson

- Common sense is not so common.

  Voltaire

FROM NOISE to COMMON SENSE

- Data are noise that has a cognitive pattern.
- Information are date that have a sense in a context/process.
- Knowledge is justified truth/belief.
- Wisdom is expertise in the fundamental pragmatics of the life (?. Ballets)
- Common sense is nothing more than a deposit of prejudices laid down in the mind before you are eighteen.

QUESTIONS

- Would you get a chance to be 200 years old with a "silicon" body, would you take it?
- Biological species almost never survive encounters with superior competitors. Can you therefore imagine that robots will eventually succeed us?
- Given the incredible power of new technologies, shouldn't we be asking how can we best coexist with them?

AI POETRY

I am not aware of two many things
I know what I know if you know what I mean.
Philosophy is a talk on a cereal box.
Religion is a smile on a dog...
Philosophy is a walk on slippery rocks.
Religion is a light in the fog ....
What I am is what I am.
Are you what you are or what?

CLOSING THOUGHTS

The potential the GNR-revolution provides are fantastic. It is, however, not clear how far will be society willing to go.

COOKING ROBOT