

## The Entanglement of Control and IT: Intelligent Control in Mechatronics

**Okyay Kaynak**

(With acknowledgments to Randy Glasbergen!)  
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## Where is Istanbul? In Asia or Europe?

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**BOTH!**  
It is the only  
city in the world  
on two  
continents!



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## Bogaziçi University (Formerly Robert College)

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Robert College was founded in Istanbul on September 16, 1863. On September 10, 1971, Bogaziçi University was officially established on what had been the Robert College campus for over one hundred years.



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## Enrollment:

TOTAL: 11206

Undergraduate: 8587

Graduate: 2619

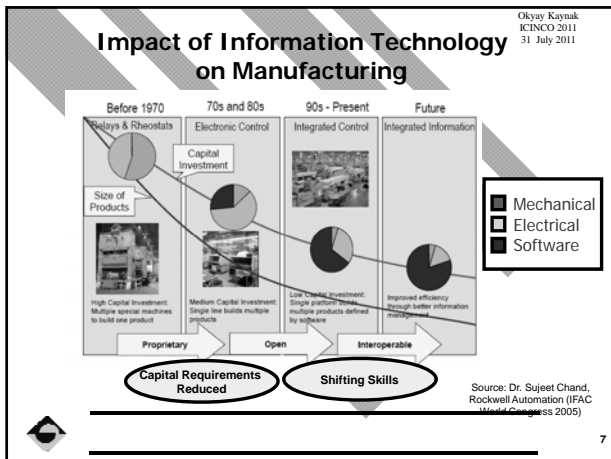
The student community includes 456  
foreign students from 45 different countries.

## Department of Electrical and Electronics Engng.

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- The most prestigious department in Turkey (one has to be among the top 700 or so out of more than a million).
- ABET accredited.
- BUEE currently has 25 faculty members, 22 teaching assistants, and several technical staff serving around 300 undergraduate students.

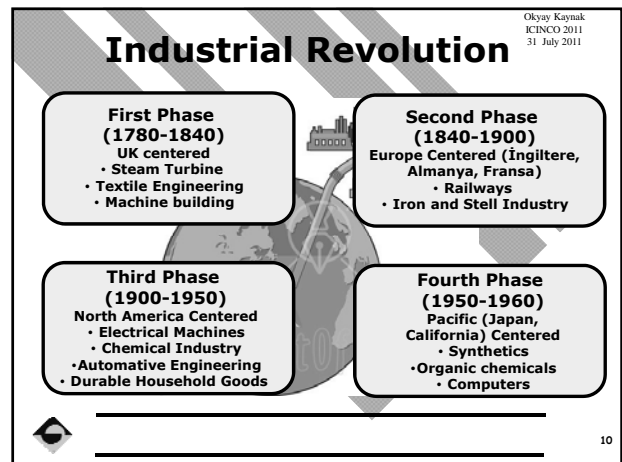
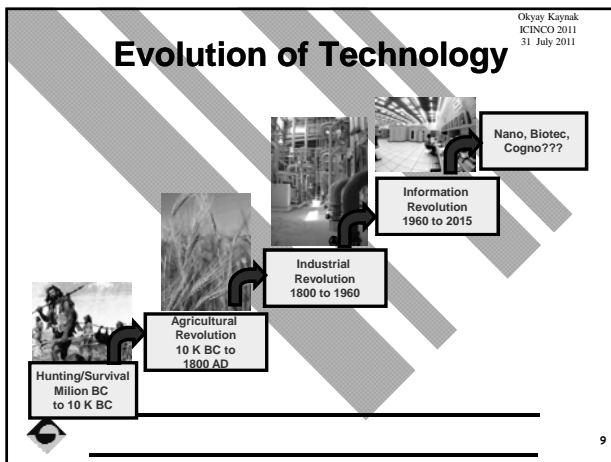
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### The Dozens of Computers that Make Modern Cars Go

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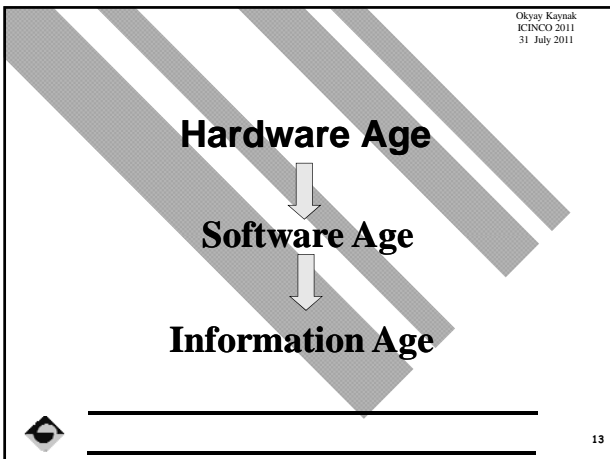
- ❑ The electronic systems in modern cars and trucks are packed with up to 100 million lines of computer code, more than in some jet fighters.
- ❑ "It would be easy to say the modern car is a computer on wheels, but it's more like 30 or more computers on wheels," said Bruce Emaus, the chairman of SAE International's embedded software standards committee.
- ❑ Even basic vehicles have at least 30 of these microprocessor-controlled devices, known as electronic control units, and some luxury cars have as many as 100.



### 20th century

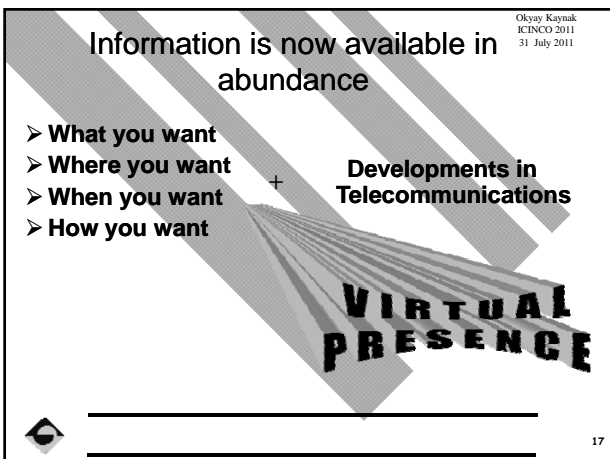
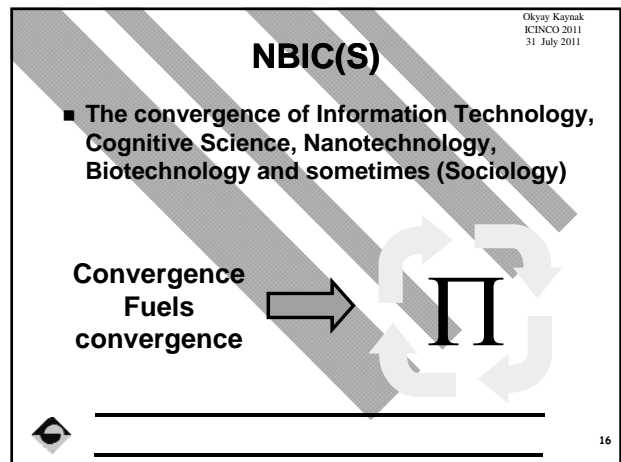
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- First half : Hardware dominated
- Early second half : Software dominated
- Last 10-15 years: Fusion of technologies
  - Optics and electronics : Optoelectronics
  - Electronics, mechanics and intelligent computer control : Mechatronics.
  - Communication and computers : IT.
  - IT and Biology: Bioinformatics
  - ??????



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- ### Erosion of Boundaries in the Information Age
- ✓ **Between industrial sectors,**
  - ✓ **Between products and services,**
  - ✓ **Between producers and users,**
  - ✓ **Between IT, communications, media, consumer electronics,**
  - ✓ **Between IT and non-IT industries,**
  - ✓ **In R&D between academia and industry between disciplines, between theoretical and applied research.**
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- ## Trend
- **Advances at the edge of traditional disciplines**
  - **Connections between different disciplines becoming the core of technologies (not multi, not inter but transdisciplinary)**
- ➔ **Convergence**  
➔ blurring
- 15



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## The Era of Tera!

Worldwide Optical Content	103 TB
Worldwide Printed Content	1,633 TB
U.S. Broadcast Media	14,893 TB
Worldwide Filmed Content	420,254 TB
Internet	532,897 TB
Worldwide Magnetic Content	4,999,230 TB
World Telephone Calls	17,300,000 TB
Electronic Flow of New Info	17,903,340 TB

Byte = 8 bits, Kilobyte = 10<sup>3</sup>, Megabyte = 10<sup>6</sup>, Giga = 10<sup>9</sup>,  
Tera = 10<sup>12</sup>, Peta = 10<sup>15</sup>, Exa = 10<sup>18</sup>,  
Zetta = 10<sup>21</sup>, Yotta = 10<sup>24</sup>

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## Slide 16

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- s1** It is the study of mind and intelligence embracing philosophy, artificial intelligence, neuroscience, linguistics, anthropology.  
sony; 02.03.2010

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# The Era of Zetta!

## The Zettabyte Scale

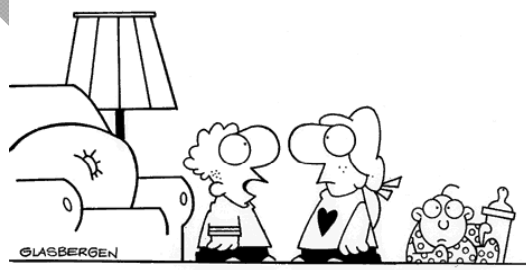
<p><b>1 Petabyte</b> 1,000 Terabytes or 250,000 DVDs</p> <p><b>1 Exabyte</b> 1,000 Petabytes or 250 million DVDs</p> <p><b>1 Zettabyte</b> 1,000 Exabytes or 250 billion DVDs</p> <p><b>1 Yottabyte</b> 1,000 Zettabytes or 250 trillion DVDs</p>	<p><b>200 Terabytes</b> A digital library of all books ever written in any language</p> <p><b>100 Petabytes</b> The amount of data produced in a single minute by the new particle collider at CERN</p> <p><b>5 Exabytes</b> A transcript of all words ever spoken</p> <p><b>100 Exabytes</b> A video recording of all the meetings that took place last year across the world</p> <p><b>150 Exabytes</b> The amount of data that has traversed the Internet since its creation</p> <p><b>175 Exabytes</b> The amount of data that will cross the Internet in 2010 alone</p> <p><b>66 Zettabytes</b> The amount of visual information conveyed from the eyes to the brain of the entire human race in a single year</p> <p><b>20 Yottabytes</b> A holographic snapshot of the earth's surface</p>
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Source: Cisco Visual Networking Index – Forecast, 2007-2012

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**“I asked my dad where babies come from.  
He says you download them from the Internet.”**

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## General trends in industry

- Knowledge is the king
- Innovation is essential
- What is *new* today becomes a *commodity* tomorrow
- Products are becoming more complex and system-based with higher performance
- Short design cycles are more common
- Markets are increasingly global and more competitive
- Design teams are a preferred approach
- Customer requirements are getting tougher
- Legislation is more and more demanding

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## Managing Change in Enterprises

Enterprises need

- Organizational structures to use IT
- Constant professional learning
- Positioning in global market
- Flexibility to act quickly

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## Mechatronics offers a *best practice* for synthesis and meeting the challenges.

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## Mecha-what???

- > Many definitions ?— Very diverse due to ever changing nature of technologies
- > Hailed as “Mechanical Engg for the 21st Century”
- > Becoming increasingly popular in MME courses
- > Criticised as “Nothing new but a bundle of existing technologies,” “No original content of technology”

Viewpoint: Mechatronics becoming the state of the art

THE field of industrial electronics, which encompasses the design, development, testing, and production of electronic systems for manufacturing and process control, is rapidly becoming the state of the art in many industries. This is due to the increasing demand for more sophisticated and reliable systems that can handle complex tasks and operate in harsh environments. The integration of electronics with mechanical systems has led to the development of mechatronics, a discipline that combines the principles of mechanics, electronics, and computer science. Mechatronics is becoming the state of the art in many industries, and it is expected to continue to grow in the future.

Energy saving is becoming an essential part of mechatronics design.

As the demand for more efficient and reliable systems increases, designers are turning to mechatronics as a solution. Mechatronics offers a wide range of benefits, including improved performance, reduced energy consumption, and increased reliability. It is becoming an essential part of many industries, and it is expected to continue to grow in the future.

IEEE Spectrum, January 1995

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## Definition of Mechatronics in 20<sup>th</sup> Century

**The synergistic integration of mechanical engineering with electronics and intelligent computer control in the design, manufacture and operation of industrial products and processes.**

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**mechatronics**

1970 1980 1990 2000

**Evolution of Mechatronics (Tomizuka 2000)**

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## Definition of Mechatronics in 21<sup>st</sup> Century

**The synergistic integration of *physical systems* with *information technology* and *complex-decision making* in the design, manufacture and operation of industrial products and processes.**

Tomizuka 2000

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## Paradigm Shift

Industrial Electronics

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Industrial Informatics

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## What is Industrial Informatics?

- *Industrial Informatics is that collection of principles and techniques that uses information analysis, manipulation, and distribution to achieve higher efficiency, effectiveness, reliability, and/or security within an enterprise.*


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## IEEE Transactions on Industrial Informatics

- Focuses on the knowledge-based factory automation to enhance industrial and manufacturing processes.
- This embraces a collection of techniques that uses information analysis, manipulation, and distribution to achieve higher efficiency, effectiveness, reliability, and/or security within industrial environment. The scope of the Transaction includes latest developments in intelligent and computer control systems, robotics, factory communications and automation, flexible manufacturing, vision systems data acquisition and signal processing.




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## YOUR KNOWLEDGE IS OUR POWER!!



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## New Generation of Products in Information Age

- More digital than analogue
- Advanced mechanical components enabled by CAD techniques
- Increasing powers of embedded IT components
- Increased complexity, ...

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**Greater flexibility  
More functions  
Higher MIQ**

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## MIQ - Machine Intelligence Quotient

- IQ stays more or less constant MIQ changes with time and is machine specific
- The dimensions of IQ and MIQ are not the same
- At this moment there is no agreed set of tests to measure the MIQ of a, say fuzzy washing machine

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## Intelligent Systems Revolution

**Man-made systems**

- Ability to reason
- Learn from experience
- Make rational decisions without human intervention

*An intelligent machine....*

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## What is INTELLIGENCE?

**"Intelligence is a mental quality that consists of the abilities to learn from experience, adapt to new situations, understand and handle abstract concepts, and use knowledge to manipulate one's environment."**

Britannica

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### How far have we got?

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**An Electric Brain Capable of Translating Foreign Languages is Being Built..**

*An headline from the popular press of 1950*

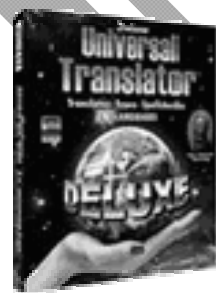


Today's most intelligent machine is far from being able to do what a child easily does, such as eating food with a knife and fork, peeling an orange, etc

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### Why so late?

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- The principle tools used in AI are symbol manipulation and predicate logic, not suitable for real-world problems
- The computing power was not available

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### Prof. Zadeh argues that

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**Soft Computing based Computational Intelligence should be the basis for the conception, design, deployment of intelligent systems rather than Hard Computing based Artificial Intelligence.**

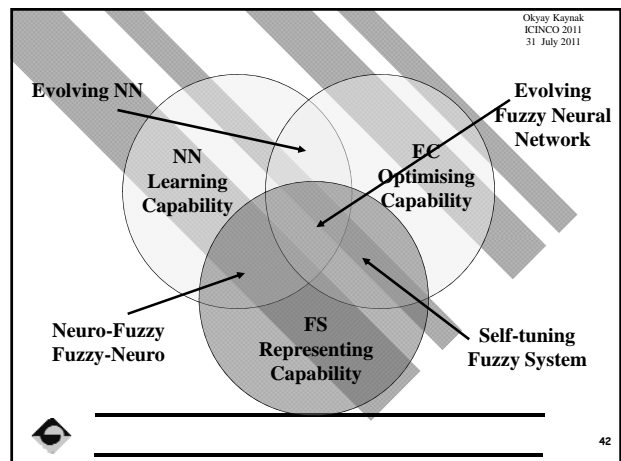
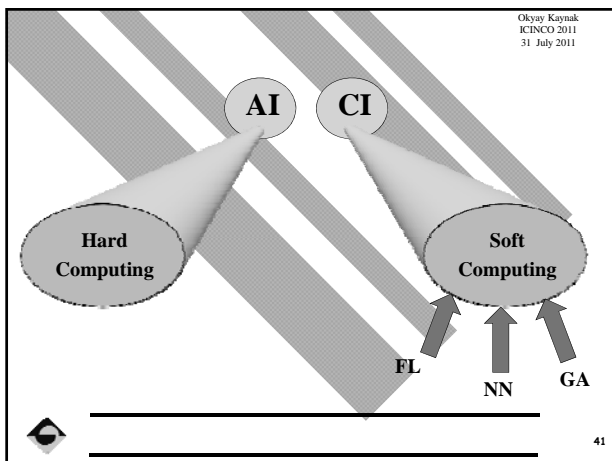
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### Hard Computing (HC) v. Soft Computing (SC)

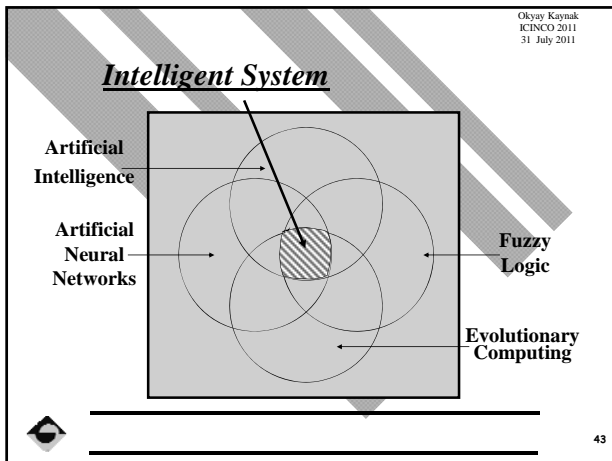
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HC	SC
<ul style="list-style-type: none"> <li>■ Bivalent Logic</li> <li>■ Numerical analysis</li> <li>■ probability theory</li> <li>■ differential equations</li> <li>■ functional analysis</li> <li>■ Mathematical programming</li> <li>■ approximation theory</li> </ul> <p><i>quantitative, precise, formal</i></p>	<ul style="list-style-type: none"> <li>■ fuzzy Logic</li> <li>■ neurocomputing</li> <li>■ genetic computing</li> <li>■ probabilistic reasoning</li> <li>■ management of uncertainty</li> <li>■ evidential reasoning</li> <li>■ rough sets</li> </ul> <p><i>qualitative, imprecise, informal</i></p>

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## Higher MIQ...

What is important about soft computing is that its constituent methodologies are for the most part synergistic and complementary rather than competitive. Thus, in many cases, a higher MIQ can be achieved by employing FL, NC, GC, and PC in combination rather than singly.

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## What in the future???

Prophetic Statements...

Can become very embarrassing in years to come..

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"This telephone has too many shortcomings to be considered as a means of communication. The device is of inherently no value to us."

"The Americans have need of the telephone, but we do not. We have plenty of messenger boys."  
— Sir William Preece, Chief Engineer, British Post Office, 1878

Western Union internal memo, 1876

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'Heavier than air flying machines are impossible'

Lord Kelvin, 1895

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'I think there is a world market for maybe five computers'

Thomas Watson, IBM, 1943

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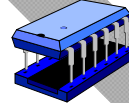
'There is no reason why anyone should have a personal computer in their home'

?

Ken Olsen, 1977

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'640K ought to be enough for everybody'

?


Bill Gates, 1981

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What progress can we expect during the next 10,000<sub>2</sub> years???

Prophecy?




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What progress can we expect during the next 10,000<sub>2</sub> years???

Futurology?



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The End of the Road??

No New Needs..  
*Today is good enough?*

Innovation Getting Harder..  
*Or too expensive?*

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Let us not forget..

*The best way to predict the future is to invent it.*

Alan Kay

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## What progress can we expect during the next 10,000<sub>2</sub> years???

- In computing environment
- In recognition technologies
- Improved MIQ of products
- Biomimicry?
- ?????

Needs of the market will be the main driver....

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## The Engine of the Information Society

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## Humanoid Robotics

### A driving force??

Manny: a full-scale android body completed by the Pacific Northwest National Laboratory in 1989 for the U.S. Army. Manny was life-sized and had 42 degrees of freedom, but no intelligence or autonomous mobility.

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### From USA Today (22 February 2002)

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## Adaptive Step in Innovative Mobility

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## Evolving ASIMO

EO	E1	E2	E3	E4	E5	E6	P1	P2	P3	ASIMO
1986	1987	1991		1991	1993		1993	1997		2000

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# Paradigm Shift in Robotics

**From 4D Assignments**  
(Dirty, Dangerous, Dull and Difficult)

↓


**To 4A Assignments**  
(Automation, Augmentation, Assistance and Autonomous)

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# RoboCup



**About RoboCup**

RoboCup™ (Originally called as Robot World Cup initiative) is an international research and education initiative. It is an attempt to foster AI and intelligent robotics research by providing a standard problem where wide range of technologies can be integrated and examined, as well as being used for integrated project-oriented education.

For this purpose, RoboCup chose to use soccer game as a primary domain, and organizes RoboCup (originally called "The Robot World Cup Soccer Games and Conferences", now called "RoboCup World Championship and Conference"). In order for a robot team to actually perform a soccer game, various technologies must be incorporated including: design principles of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning, robotics, and sensor-fusion. RoboCup is a task for a team of multiple fast-moving robots under a dynamic environment. RoboCup also offers a software platform for research on the software aspects of RoboCup.

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# Robot Soccer

*By the mid-21<sup>st</sup> century, a team of fully autonomous humanoid robot soccer players shall win the soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup...*

**A date has been registered with FIFA: 17 July 2050**

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# Roadmap to Achieve the Goal of RoboCup

```

    graph TD
        Walk --> RunJump[Run and Jump]
        Walk --> JumpTurn[Jump Turn]
        Walk --> ObjectTrack[Object tracking]
        Walk --> ObjectRec[Object recognition]
        RunJump --> RunJumpTurn[Run, Jump, and Turn]
        RunJump --> KickDir[Kick to desired directions]
        RunJump --> KickMov[Kick a moving ball]
        RunJump --> KickStat[Kick a stationary ball]
        KickDir --> PenKick[Penalty Kick]
        KickStat --> PrecLeg[Precise leg motion control]
        KickStat --> CollAvoid[Collision avoidance]
        KickStat --> ObjFollow[Object following]
        KickStat --> ObjTrack[Object tracking]
        KickStat --> ObjRec[Object recognition]
        KickStat --> MultiTrack[Multiple objects tracking]
        PenKick --> BasicBeh[Basic player behaviors]
        KickDir --> BasicBeh
        KickMov --> BasicBeh
        KickStat --> BasicBeh
        BasicBeh --> Teamwork[Teamwork behaviors]
        BasicBeh --> AdvHumanoid[Advanced humanoid teams]
        Teamwork --> ReactCoach[Reacting to Coach's Command]
        Teamwork --> HighAware[Highly sensitive situation awareness]
        Teamwork --> StrategicPlan[Strategic Planning]
        Teamwork --> RealTimePlan[Real Time Planning]
        Teamwork --> Learning[Learning]
        ReactCoach --> AdvHumanoid
        HighAware --> AdvHumanoid
        StrategicPlan --> AdvHumanoid
        RealTimePlan --> AdvHumanoid
        Learning --> AdvHumanoid
        ObjTrack --> SepSpeech[Separation of Speech and Noise]
        SepSpeech --> AuditoryScene[Auditory Scene Analysis]
        SepSpeech --> SpeechRec[Speech Recognition]
        SepSpeech --> ReactCoach
        SepSpeech --> HighAware
        SepSpeech --> StrategicPlan
        SepSpeech --> RealTimePlan
        SepSpeech --> Learning
    
```

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# Nao - Robocup Edition

Nao has been selected by the International Robocup Committee as the successor of the Sony robot dog Aibo, as the new official platform of the Robocup Standard League.

Thus, the next edition of the Robocup, in July 2008 in Suzhou in China, will feature a 16 university teams from all over the world "Nao League. They will be able to use the excellent cognitive and physical abilities of dozens of Nao (4 in each team) during soccer plays.




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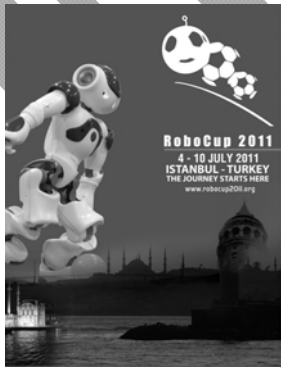
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# NAO

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**RoboCup 2011**  
4 - 10 JULY 2011  
ISTANBUL - TURKEY  
THE JOURNEY STARTS HERE  
www.robocup08.org

**43 countries, 400 teams  
and 3000 participants!**

**One of the best among the  
15 RoboCups that have  
taken place.**

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## Research Issues in Humanoid Robots

- Perception
- Human-Robot Interaction
- Learning and Adaptive Behaviour
- Legged Locomotion
- Arm control and dexterous manipulation
- Materials
- Energy

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## Mechatronics / Robotics

Ambient  
Intelligence

Societal  
Challenges

**Increased robot-human  
and robot-machine interaction**

- improving our performance
- extending our senses and physical capabilities

**Migration of robots  
out of Shopfloors** } **Usability - Adaptability  
Robustness - Safety**

- Service Robots, Field Robots
- Robot Assistants  
(Worker Assistants,  
Personal robots, cyber-companions)

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## Cognitive Perception

Sensors

Storage &  
Computing

Software &  
Computing

**Perception**  
Signal Processing  
Sensor Fusion  
Pattern recognition - 3D modeling

**Artificial Intelligence**  
Intelligent agents  
Reasoning  
Memory & knowledge organisation

**Cognitive Perception**

**Understanding Intelligence**

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## What can nature teach us?


- The most successful control systems on earth are biological ones.
- What can we learn from them?
- Conversely, can there be anything that biological science learn from the control-theoretic viewpoint?

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## Biomimicry?

- Locusts are experts at avoiding collisions. They fly in swarms many millions strong without bumping into each other. Can we learn from their simple neural machinery to design a collision sensor to warn of impending collision using visual information?
- Can we learn from a fly how to land very gracefully as it does at the edge of a plate?



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## The Big Dog



Boston Dynamics

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## LS3 Legged Squad Support Teams

- Will carry up to 400 lbs of gear and enough fuel for missions covering 20 miles and lasting 24 hours;
- The development of LS3 will take 30 months, with first walk out scheduled for 2012.



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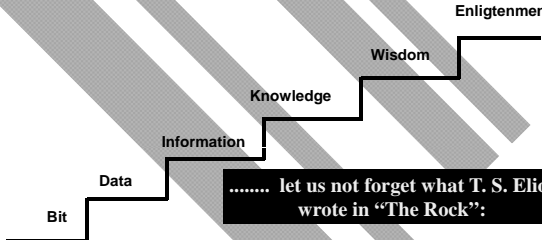
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**As we climb up the ladder of knowledge, .....**

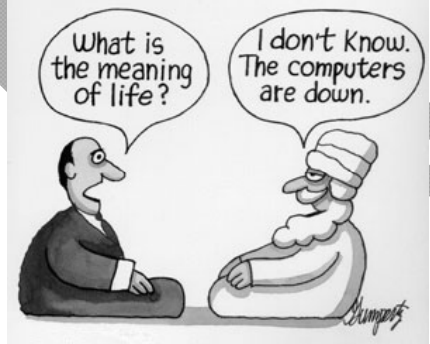


..... let us not forget what T. S. Eliot wrote in "The Rock":

*Where is the life we have lost in living?  
Where is the wisdom we have lost in knowledge?  
Where is the knowledge we have lost in information?*


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## Thank you for your attention!!

AS YOU CAN CLEARLY SEE IN SLIDE 397...

GAAAAH!

POLYMER POINT POISONING.

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